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Lake Sturgeon in the Saskatchewan River:

Spawning, habitat and tagging

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LAKE STURGEON IN THE LOWER SASKATCHEWAN RIVER: SPAWNING SITES, GENERAL HABITAT, AND TAGGING, 1994 TO 1997

by

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A report to the

Interprovincial Sturgeon Steering Committee

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EXECUTIVE SUMMARY

Saskatchewan has resident populations of lake sturgeon in the Saskatchewan River system, and in the lower Churchill River. They are typically residents of large rivers or lakes.

The sturgeon population in the lower Saskatchewan River (Cumberland Lake area) was apparently healthy in the 1950s. Nonetheless, problems were observed in surveys between 1954 and 1990, particularly losses of habitat, higher mortality, and lower reproduction.

A proposal for protection and restoration of the population and habitat was sent to local users in Cumberland House, fisheries staff, and other agencies (Wallace 1991). A committee was established to discuss concerns and to review plans and progress.

This report covers spawning sites, general habitat, and tagging of sturgeon. The area includes the Saskatchewan River (from EBCampbell dam downstream to Manitoba) and tributaries (Torch River, Mossy River, and Tearing River). A companion report covers radio-tracking and index fishing, extending downstream to Cedar Lake (Wallace and Leroux 1999).

SPAWNING SITES

Sturgeon congregate and spawn below rapids in late May or early June. Local knowledge, maps, and earlier field-work suggested that the Torch River, EBCampbell tailrace, and Bigstone Rapids were high-priority sites. The Mossy and Tearing Rivers were also surveyed.

Methods included attempts to observe spawning behaviour, examine mature-size sturgeon (for free-running eggs or sperm, or swollen vents), and use drift-nets to catch sturgeon fry.

Visual observation of spawning behaviour was not possible. The large size and depths of some rapids (especially Bigstone Rapids) and the turbid water at most sites prevented it, even along the shoreline.

Several spawning sturgeon were caught, notably one female with free-running eggs in June 1996 at Bigstone Rapids, a second female which contained ripe eggs, and free-running males at Bigstone Rapids, EBCampbell area, and Torch River.

Sturgeon fry were captured in only one drift-net sample in three years: June 1995 in the Torch River. Numerous fry of other fish species were caught: white suckers, northern pike, burbot, walleye, shiners, and others.

The Torch River and creeks contain numerous rapids of good spawning potential. Mature sturgeon were caught frequently at its mouth and one radio-tagged sturgeon moved into this river.

EBCampbell tailrace provides suitable substrate (mostly cobble). Several free-running males were caught, and two radio-tagged sturgeon moved into this area at spawning time. The former Tobin and Squaw Rapids provide good substrate, but lack water.

Bigstone Rapids provides good spawning substrate and waterflow. Spawning was confirmed by the presence of spawning females and males.

Mossy River has moderate habitat in its lower areas, and better habitat upstream. Reports of small sturgeon in the area suggest spawning at its mouth or upstream. Tearing River contains spawning habitat, the first good site upstream from Cedar Lake.

TEMPERATURES

Lake sturgeon spawning peaks at 12 to 15 °C. Eggs incubate about a week, and the young fry live on their yolk-sac for another week before drifting.

The Torch River rapids reached spawning temperatures in mid or late May, consistently one or two weeks before EBCampbell tailrace. Smaller rivers typically warm before larger rivers, and ice-cover leaves rivers sooner than reservoirs.

Dates of spawning in the Torch River were predicted from air temperatures at Nipawin and Prince Albert weather stations. This may be useful for planning outflows from the dam upstream at Candle Lake during spawning.

Spawning temperatures occurred in late-May to mid-June at EBCampbell and Bigstone Rapids. Optimal temperatures lasted from one to two weeks at each site, depending on weather.

GENERAL HABITAT

Depths along more than 200 km of river channels and Cumberland Lake were echo-sounded. The abundance of bottom-dwelling organisms were also surveyed to assess food conditions.

EBCampbell area is less than 10 feet deep, the Torch River under 6 feet, and some side-channels are inaccessible at normal waterlevels. On the other hand, the mainstem river has

a maximum depth of 50 feet in Saskatchewan and 30 feet in Manitoba, the Mossy River reaches 23 feet, and the pool of Bigstone Rapids is 21 feet deep.

Food conditions varied considerably, with some areas possibly limiting sturgeon growth. Sandy sites had low numbers of small prey, while clayey sites had ten times more (and larger) specimens. Prey abundance was poor in the EBCampbell area and Centre Angling River, and good in side-channels and downstream of Bigstone Rapids.

TAGGING AND MIGRATIONS

Determining the present abundance of sturgeon would allow comparisons to historical abundance and to other populations.

Sturgeon were caught by gill-nets and baited hooklines. Orange tags were used for visual detection of recaptured fish. Later, electronic "PIT" tags were injected into fins to improve long-term detection of tags.

About 126 sturgeon were tagged (ranging from 2.5 to 58 pounds), and 14 were recaptured. Most were recaught downstream of their tagging site, due to natural behaviour or stress from handling. The longest movement by any sturgeon was 60 miles (85 km) in four months. Sturgeon tagged at the Torch River were all recaptured locally, up to three years later.

The number of tagged fish was less than the 500 needed for simple estimates of abundance. A more complex, continuous tag-recapture approach began in 1996, as part of the index fishing program.

MISCELLANEOUS

Reports of large sturgeon in spillway pools below EBCampbell dam were investigated in May 1994, June 1994, and August 1995. Nine sturgeon were caught, tagged, and released below the power-station. Some had survived in these pools over-winter.

A visual assessment of the Sturgeon-weir River on Namew Lake showed good spawning habitat. This agrees with historical and recent reports of lake sturgeon in parts of Namew Lake.

CONCLUSIONS

Spawning in Torch River rapids and Bigstone Rapids was confirmed. Potential spawning in the EBCampbell tailrace, the

former Tobin and Squaw Rapids (historically), and the Tearing River was confirmed by the presence of sturgeon in spawning condition.

The suitability of most rapids, relative to other rapids and to historical conditions, cannot be assessed by visual methods alone. Use of physical-habitat simulation models and species-preference curves appears to be necessary.

Tributaries (such as the Torch River) reach spawning temperatures about one week earlier than Bigstone Rapids. In turn, Bigstone Rapids is suitable about one week before the EBCampbell area.

Water temperatures are cooler during spawning season below EBCampbell area (for about 20 km) than downstream. Abundance of food-organisms is also lower in this particular area.

Any proposal to restore spawning habitat in the former Tobin and Squaw Rapids (or EBCampbell tailrace) to historical conditions will be complicated by cooler water at spawning time and poor food conditions nearby, as well as by the changes in flow regime.

General habitat conditions are similar to those of other sturgeon populations. Deeper areas in rivers provide suitable over-wintering habitat, and many areas have suitable food conditions.

RECOMMENDATIONS

Recovery of this sturgeon population depends on action on both habitat and harvests. Accordingly, actions selected from these recommendations must collectively meet the test of addressing both of these issues.

Management on the population should continue to be a co-operative effort of provincial agencies, communities, and resource users.

Protection of the habitat and protection from local over-harvest is required, especially during spawning in former and present sites.

Continued harvesting of lake sturgeon from the lower Saskatchewan River will allow the present decline to continue, and may delay or prevent the recovery of this population.

Stakeholders should seriously consider restrictions on commercial and subsistence fishing. Information on subsistence

fishing and cultural uses by First Nation and other aboriginal people is needed.

Agencies responsible for allocation and usage of water should analyse the effects of enhancing water flows in the former Tobin and Squaw Rapids for spawning.

Radio-tagging should be continued until late 1999. Index fishing should be continued for biological, economic, and action-plan reasons.

Further trials of egg collection for re-stocking should be undertaken.

These recommendations were based on work in both the present report and a companion report (Wallace and Leroux 1999).

ACKNOWLEDGMENTS

Many people were involved in the field and report components of this project. My appreciation goes to all of them.

Alfred Joe Goulet and Howard McKenzie (Cumberland House) contributed local knowledge and experience on the river. They undertook a variety of field activities, maintained records, and acted as important contacts within the community.

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Members of the steering committee reviewed the scientific aspects of this report during 1998 and 1999. Verbal and written comments were received from Alfred Joe Goulet, Howard McKenzie, Anne Acco, and John Carriere (Cumberland House), Chief Pierre Settee (Cumberland Cree Nation), Robert McGillivary (Opaskwayak Cree Nation), Scott Findlay (IREE University of Ottawa), Llewellyn Matthews (SaskPower), Maynard Chen and John Durbin (Saskatchewan Environment and Resource Management), Doug Leroux (Manitoba Natural Resources), and Dennis Windsor (Manitoba Hydro). Their comments and suggestions were appreciated.

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INTRODUCTION

Saskatchewan has resident populations of lake sturgeon (Acipenser fulvescens) in the Saskatchewan River system, and in the lower Churchill River near Island Falls. Throughout their range, lake sturgeon are residents of large rivers and large shallow lakes (Scott and Crossman 1973).

Lake sturgeon grow relatively slowly and females mature rather late at 20 to 25 years old. Each female requires from 4 to 8 years between spawnings to produce ripe eggs. From pre-spawning congregations to movement of fry out of the area takes from 4 to 6 weeks.

The sturgeon population in the Cumberland Lake area was apparently healthy in the 1950's. Reproduction and recruitment of young sturgeon were acceptable, and annual mortality rates were low. Nonetheless, several problems in the population were observed in periodic surveys between 1954 and 1990. As habitat was degraded and mature fish were removed, the population became smaller and younger, annual mortality became unsustainably high, and reproduction and recruitment fell. Reasons for the decline were examined in two earlier reports (Wallace 1991, Findlay et al. 1995).

The population is not capable of sustaining itself under existing habitat conditions and fishing harvests. A proposal for the protection of the population and restoration of suitable habitat conditions was sent to local users in Cumberland House, fisheries staff within Manitoba and federal departments, and other interested managers and observers (Wallace 1991).

PROJECT

Restoration of the sturgeon population in the Saskatchewan River from E.B.Campbell dam (formerly Squaw Rapids dam) in Saskatchewan downstream to Cedar Lake and the Grand Rapids dam in Manitoba requires five components, according to Fisheries Branch (M. Chen, pers. comm.):

- Habitat inventory and evaluation.
- Population assessment.
- Habitat protection, improvement, or creation.
- Population restoration and/or enhancement.
- Co-management with local stakeholders, and assessment of program effectiveness.

A committee of resource users (e.g. Saskatchewan and Manitoba commercial fishermen, First Nations users, and Metis users), staff from federal Fisheries & Oceans, Manitoba (Northwestern Region - Fisheries) and Saskatchewan (Fisheries Branch), and staff from SaskPower meets periodically to discuss concerns and to review plans and progress. Meetings have been open to all interested people from the communities and other organizations.

SaskPower contributed $ 25,000 annually for 4 years to examine critical habitat (such as spawning sites) and population assessment (such as the effects of fishing) in Saskatchewan. Fisheries Branch planned field surveys, contributed one person and available equipment, and analyzed biological and habitat data from this project.

The surveys and field-work were designed to address the components of 'Habitat inventory and evaluation' and 'Population assessment'. Plans included providing information for habitat protection or creation, and population restoration and/or enhancement.

Two project-workers (Howard W. McKenzie and Alfred J. Goulet) from Cumberland House were hired on the basis of experience in traveling and fishing locally. Rental of boats & motors and purchase of gas, food, and gear were done in the Cumberland House area when possible.

Field-work extended from May to August of 1994, 1995, and 1996, with occasional work in autumn and mid-winter. In 1997, field-work was terminated at the end of July. The general plans and techniques of the field-work are described, although actual work sometimes differed from this for various reasons (such as demands at more than one site, gear breakdown, inclement weather, or other reasons).

Other agencies worked on this project or are working independently on related studies: Department of Fisheries and Oceans staff (R. Fudge, Winnipeg) worked on fry drift and provided equipment in 1994 and 1995. Manitoba staff from The Pas worked co-operatively on radio-tracking and index fishing from 1995 to 1997 (see companion report by Wallace and Leroux 1999). Manitoba staff continue to study northern rivers with local communities, rearing young sturgeon, and re-assessing provincial management. University of Manitoba faculty are examining the physiology and habitat needs of young sturgeon, and their aquaculture and stocking potential.

AREA DESCRIPTION

The area of field-work covers from the Tobin Lake dam and power-station downstream into Manitoba, including the New Channel, Torch River, the larger river-channels such as Mossy River and Centre Angling River, and Cumberland Lake (Figure 1).

About 1873, the Saskatchewan River overflowed its banks near the Torch River, joined existing rivers, and cut new channels to create a delta (Smith et al. 1989). Some former rivers retained their names after incorporation. The present mainstem Saskatchewan River from upstream to downstream comprises:

EBCampbell spillway (6 km long),
Saskatchewan River (27 km long),
New Channel (22 km),
Centre Angling River (about 26 km),
Saskatchewan River (16 km),
Bigstone Cutoff (6 km),
Saskatchewan River (about 209 km),
Cedar Lake (117 km).

The lowest portions lie partly inside Manitoba, although the present report concerns only work done in Saskatchewan.

The upper portion of Saskatchewan River is generally sandy due to sediment deposition in Tobin Lake. The New Channel and Centre Angling River are well defined, with some natural levees along the river-banks (Smith et al. 1989) and secondary channels (e.g. Steamboat Channel and North Angling Channel). The next area consists of the Saskatchewan River and inter-connecting channels. The Bigstone Cutoff carries flow from the

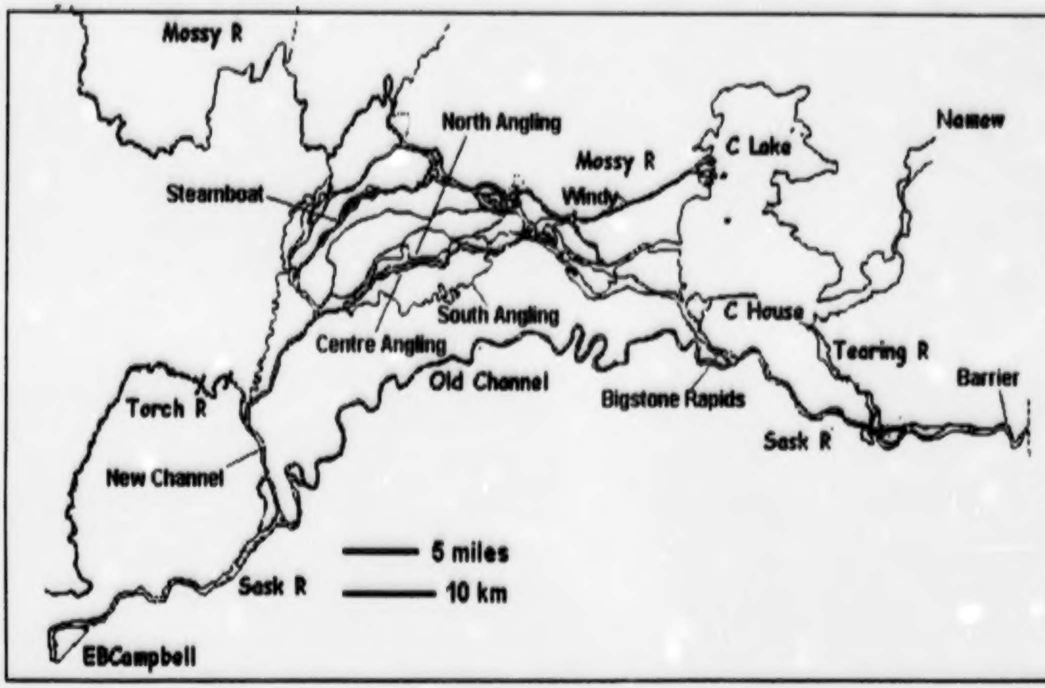


Figure 1. Map of lower Saskatchewan River and other channels in the Saskatchewan project area.

Saskatchewan River, and outflow from Cumberland Lake (both directly and via the Bigstone River). The Tearing River provides another outlet for Cumberland and Namew Lakes, since an earthen dam at the outlet remains breached. The lowest portion of the Saskatchewan River is again well-defined all the way to The Pas. About 30 km below The Pas, it is again surrounded by low-lying land and changes from "hardpan bottom" to silt and organic sediments (Cober 1968).

SPAWNING SITES

Sturgeon congregate and spawn below rapids in late May or early June, the eggs incubate one week, and then the young fry live on their yolk-sac for one week before drifting downstream into quiet-water habitats (Scott and Crossman 1973). Criteria for spawning habitat are better known than for rearing and juvenile habitat.

Evaluation of sturgeon habitat in Saskatchewan, and downstream into Manitoba, was focused primarily on spawning sites. The Saskatchewan River and its tributaries are generally low-gradient, so sites with rapids tend to be localized.

Several approaches were used to examine and confirm likely spawning sites. Preliminary work used local knowledge, topo maps, and previous field-work to priorize possible sites. This was followed by field-work on spawners, fry drift, and fry marking at some of the sites.

PRELIMINARY

Local knowledge had identified sites of known activity and mature sturgeon. Descriptions from other biological studies and maps of habitat conditions indicated some sites. There were five or six sites with known or potential spawning.

Torch River: Rapids are shown on topographic maps along much of the Torch River. Several rapids with good potential (typically 20 to 100 m long) were observed in earlier field trips. Elders also reported spawning in one tributary, Missipuskiow Creek.

Tobin and Squaw Rapids: These large rapids on the mainstem Saskatchewan River were formerly 6 km long. Historically, they were the first major rapids upstream from Grand Rapids (Voligny 1917), which is the presumed natural range for this population. The river-bed shows good substrate, ranging from cobbles to large boulders.

Tailrace: The power-station lies near the upper end of a stretch of fast water, historically known as Squaw Swifts. This is about 5 km long, with cobble or stony substrate. The river-bed appears to be physically stable, although waterflows do not follow natural patterns due to hydro-electric power generation.

Bigstone Rapids (locally known as Saskatchewan River Rapids): Concentrations of mature and ripe sturgeon have been reported and observed at spawning time. These moderately large rapids

show large, broken rocks near shore. Water from the Saskatchewan, Mossy, and other rivers, and from Cumberland and Namew lakes, all presumably contribute to these rapids.

Mossy River: There are reliable reports of young sturgeon in the lower reaches of this river, and around nearby islands in Cumberland Lake (J.V. Carriere, pers. comm.). This suggests either spawning in these areas, or drifting by young-of-the-year sturgeon from upriver which then settle and feed locally.

Tearing River: There are reliable historical reports of sturgeon spawning from local people, especially elders. Lack of water flow (due to a barrier constructed to raise water levels in Cumberland Lake) prevented field evaluation in some years.

Others: There are few (if any) obvious spawning sites further downstream. Elders have reported some spawning in tributaries under former habitat conditions (e.g. 1940s). Project workers visually confirmed the lack of suitable sites at present (R. Fudge, pers. obs.).

Rapids in the Torch River, the EBCampbell tailrace, and Bigstone Rapids were the highest-priority sites for field-work. The Mossy River was surveyed near Cumberland Lake, although this river is not directly affected by habitat changes. The Tearing River was only examined in later years because flow was initially blocked upstream at the outlet from Cumberland Lake.

SPAWNING

The most direct confirmation of the use of potential spawning sites are observations of spawning, including the release of eggs and sperm for fertilization. The second most direct is observation of spawning behaviour, such as groups of two or three males following a large, female sturgeon.

METHODS

Sturgeon were observed when caught near spawning sites to find ripe and running specimens. Determinations were based on the following criteria, in order of approximate reliability: free-running eggs or sperm; manual expression of sperm; swollen, reddened gonopore or vent in females.

Experience in observing and handling sturgeon for artificial spawning, photos of gonopores of spawning sturgeon in Michigan (N.A. Auer, pers. comm.), and verbal and written descriptions of spawning condition were used.

RESULTS

Direct observation of spawning and spawning behaviour was not possible due to the size of some rapids (standing waves up to 2 m high) and the turbid water at most sites (Secchi-disk depths less than 10 cm). Typically, rock and cobble substrate suitable for spawning are found shore-to-shore in these areas, meaning sturgeon do not often approach shore (Howard McKenzie, Joe Goulet, and others, pers. comm.).

There were several spawners observed, most notably a female with freely running eggs. She was caught 6-June-1996 at Bigstone Rapids, measured 131 cm (52 inch) and 14.8 kg (33 pounds), and was radio-tagged with #48.090. Given her state, she must have spawned at Bigstone before swimming or drifting downstream into Manitoba (Wallace and Leroux 1999). Another female of several being held at Bigstone in 1996 was checked and had ripe (but not running) eggs, and was sutured and released.

Other conclusive observations were males showing sperm (freely or expressed on handling):

23-May-1995	Bridge (near Bigstone Rapids)	103 cm	8.4 kg
15-Jun-1995	EBCampbell tailrace	110 cm	11.5 kg
26-May-1997	Torch River outlet	138 cm	20.4 kg
26-May-1997	Torch River outlet	122 cm	15.0 kg
30-May-1997	Bigstone Rapids	107 cm	9.1 kg

These observations do not necessarily reflect the abundance of spawners, since many specimens which appeared to be mature and ripe were not checked further. Some observations of expressive males were also not recorded.

FRY DRIFT

The next most direct way to confirm spawning and hatching at a site is to capture fertilized eggs or newly hatched fry (or larvae). If necessary, hatching dates can be calculated from the stage of egg development or from the size of fry (see Detlaf et al. 1981 cited in LaHaye et al. 1992, Wang et al. 1985, Kohlhorst 1976) to ensure that they came from local spawning sites, and did not drift from upstream sites. Even

then, flow velocities of the river are known, the spawning site can be confirmed.

METHODS

From 1994 to 1996, several methods were used to locate sites with eggs or fry and to estimate their relative abundance.

Hand-pumping:

We initially tried hand-pumping sturgeon eggs off the bottom, using a bilge-pump and flexible hose. This has been successful for walleye eggs in shallow rapids (Newbury and Gaboury 1992). However, the deep water, moderate to fast flows, and large rocks of our sites meant that results were not encouraging and this method was abandoned early.

Drift-nets:

Drift-nets were placed below potential spawning rapids to collect either eggs or fry. These nets are typically small and tapered, with fine-mesh (0.5 to 0.8 mm openings). Various models were available for field use, ranging in size from mouth openings of 15 to 50 cm (or 0.02 to 0.15 m^2 area) and lengths of 1 to 2.5 m.

We designed our drift-net survey to have a reasonable chance of collecting fry. Other studies suggested that sturgeon eggs or fry would be collected within 1 to 4 hours with our gear if spawning sites were "good" (see Appendix A).

In 1994, two crews of two people worked on drifting fry. Drift-nets were set for periods ranging from 15 minutes to more than 12 hours, typically for a few nights during each visit to a location.

The Wisconsin net was a large net designed to fit a steel frame which sat on the river bottom (R. Fudge pers. comm.). Its advantages were the large mouth (about 0.5 by 0.7 m) and rugged materials, and its self-orientation on bottom.

By 1995, PAIF and torpedo-style nets were the primary gear. The PAIF nets are moderately large yet light-weight, with a 50 by 30 cm mouth. They were set in shallow water using steel rods driven into bottom, and anchored in deep water using added ropes and floats. They also have a large length-to-mouth ratio to improve filtering and reduce clogging of the mesh (Wallace 1987).

Torpedo nets are very small (15 cm diameter), with a conical

mouth-extension, in a rigid frame. They are portable and easy to handle, and have a large length-to-mouth ratio. The mouth-extension should reduce the 'bow wake', which can carry fry around the net (Pavlov et al. 1994). Several nets will cover more sites at one time for the same total amount filtered, which can be an advantage.

Floating drift-nets:

Floating drift-nets will collect eggs (and sometimes fry) which are scoured from the substrate, if the nets are placed in 'upwelling' currents (M. Gaboury pers. comm.). Usually they are suspended from bridges, but none of our sites had any overhead structures until late 1996. Accordingly, we anchored nets and adjusted the point of attachment of the anchor rope to achieve a planing action. 'Porpoising' of the net was frequently observed, especially at flow velocities above 1 m/s. Occasionally, they captured 8-cm long clams and 5-cm rocks from 3 m depths at Bigstone Rapids.

Drift-net collections were preserved in 5 to 10% formalin, and fish larvae (or fry) were sorted and identified later. Identification was based on the following sources: Kempinger (1988), Mansueti and Hardy (1967), Lippson and Moran (1974), notes and photos from D. Leroux and R. Fudge (pers. comm.), and Conte et al. (1988).

RESULTS

In 1994, there were problems at several sites from moderate to high turbidity and relatively deep spawning sites. Serious clogging of mesh by sediment, algae, and other particles was seen. We did not measure the effect of reduced flows through nets. Over long periods, drift-nets may filter only 80% effectively in clear water, less than 70% in turbid water, and near 0% in high turbidity (Veshchev et al. 1994, Franzin and Harbicht 1992, Wallace 1987).

Deeper spawning sites (especially Bigstone Rapids) were difficult to sample. The Wisconsin net, which would have been suitable for deep water, was heavier than two or three people could safely handle from our 5-m long boats, and required larger anchors than were available. The PAIF nets were awkward as each one needed several anchor ropes, one or two floats to hold the mouth open, and a float for retrieval. We were also unable to confirm that the PAIF net mouth was oriented vertically and effectively when set in deep water.

High waterlevels caused additional problems in 1995. Flows

increased about the time fry were expected to drift in the main river. Increased scouring caused river-bed sands to shift and completely fill two drift-nets (one PAIF and one torpedo net) in the Mossy River, so that they could not be raised and were lost. Another PAIF net was lost below Bigstone Rapids due to unusually fast currents and frayed anchor ropes.

In 1994, about 31 samples from drift-nets were collected from late May to July. In 1995, about 63 samples were collected from late May until late July (Table 1).

In 1994, no sturgeon eggs or fry were found in the samples examined. White suckers were collected frequently and northern pike, burbot, walleye, and others were seen occasionally (Table 2). Since sturgeon were not caught, either more samples were needed at these sites, or the abundance of drifting fry is low in this population even at potentially good sites.

In 1995, about 10 sturgeon fry were collected from the Torch River on June 15. This the first known report of sturgeon fry for Saskatchewan. None were seen in the few examined samples from EBCampbell, Bigstone Rapids, or Mossy River (Figure 2). Many of the 1995, and all of the 1996 samples, remain to be analyzed (see Tables 1 and 2).

Table 1. Numbers of drift-nets set for fish larvae (fry), 1994 to 1997.

Category[a]	Number of sets[b] 1994	1995	1996	Category	Number of sets 1994	1995	1996
Area:				Type of gear[c]:			
Torch River	15	15	18	Egg sucker	1	0	0
EBCampbell area	2	31	3	Floating	12	0	0
Bigstone Rapids	12	12	9	PAIF	5	44	36
Mossy River	3	4	0	Wisconsin	13	0	0
Cumberland Lake	1	0	3	Torpedo	0	18	0
Tearing River	0	0	3	Cone	0	1	0
Month:				Duration (hour):			
May	2	1	0	less than 1	4	0	0
June	30	39	20	1 to 5	7	2	3
July	1	23	16	5 to 10	9	10	11
				10 to 15	9	51	7
				more than 15	4	0	15

[a] The various categories (for example, 'Areas' and 'Types of gear') are shown separately, and do not relate to one another.

[b] No drift-nets of any kind were set in 1997.

[c] See text for descriptions of gear-types.

Table 2. Number and identifications of fry caught in drift-nets, 1994 to 1997.

Area	Month	Samples	Number fry	Number sturgeon	Others identified[a]
1994					
Torch	May	2	180	0	Suckers, unidentified.
	June	3	62	0	Suckers, unidentified, insects.
	July	2	27	0	Emerald shiners, suckers.
EBCampbell	June	2	0	0	Insects, snail.
Bigstone	June	4	81	0	Pike, sticklebacks, burbot ...
Mossy	June	1	9	0	Johnny darters ...
Centre Angling	July	1	6	0	Shiner, perch, stickleback ...
...	...	17	...	...	Samples not examined yet.
1995					
Torch	May	2	0	0	
	June	14	928	13	Suckers, trout-perch, pike ...
EBCampbell	May	1	0	0	
	June	18	...	0	Samples at Fisheries & Oceans.
Bigstone	June	4	6	0	Pike, burbot, salmonid.
	July	3	4	0	Burbot, minnow, perch.
Mossy	June	5	23	0	Burbot, minnows.
...	...	16	...	...	Samples not examined yet.
1996					
Torch	June	11	...	...	Samples not examined yet.
	July	7	...	...	Ditto
EBCampbell	June	3	...	...	Samples not examined yet.
Bigstone	June	6	...	...	Samples note examined yet.
	July	3	...	...	Ditto
Cumberland	July	3	...	...	Samples not examined yet.
Tearing	July	3	...	...	Samples not examined yet.

[a] All fry examined were identified as lake sturgeon or "others". Not all "others" could be identified to species, and many identifications were not attempted.

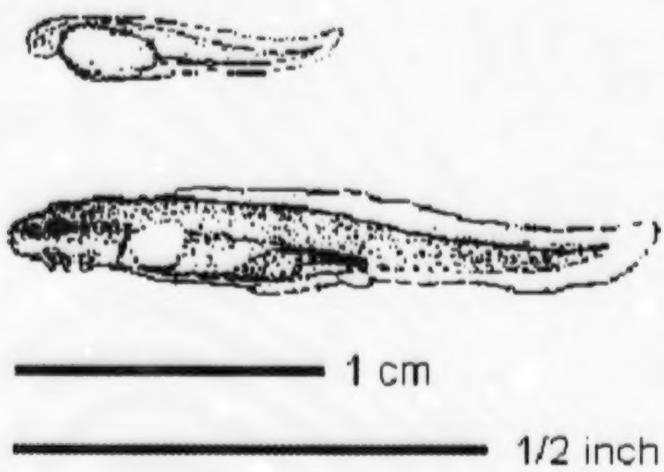


Figure 2. Drawings of sturgeon fry. The upper fry is recently hatched and still has a large yolk-sac; the lower fry is ready to drift and begin feeding. Adapted from Kempinger (1988).

Hatching and drifting by sturgeon species depend on cumulative temperatures; drifting typically occurs when external feeding begins. In 1995, water temperatures were recorded more frequently near the spawning areas than in 1994. This was to ensure that drift-netting included as many days during the likely period of drift as possible.

Generally, similar water temperatures occurred first in the Torch River, about 5 days later at Bigstone Rapids, and another 5 days later in the EBCampbell area. This allowed us to work several days at each site under suitable water temperatures.

FRY MARKING

The total number of fry drifting is usually estimated from the number of fry caught and the ratio of the river's discharge to the amount of water filtered by the net mouth (Veshchev et al. 1994).

The complete lack of fry in 1994 drift-nets suggested that fry capture was not guaranteed, even with greater effort. Therefore, the abundance of fry might not be obtainable, either as a total number of fry or as an index (e.g. catch per hour, or catch per 1000 m^3).

Trials were run in 1995 to improve detection of fry, and to estimate the maximum number of fry which could drift in a period but not be detected.

METHODS

The procedure was to set drift-nets, then release a known number of small, marked items upstream of the drift-nets, and to count the number of sturgeon fry and marked items caught.

If these items were carried by the current similarly to fry and were recaptured, then the number of fry drifting could be determined. At the very least, we could estimate the maximum number of fry which escaped detection with the gear and time available. The method depends on reasonable numbers of items and fry being recaptured in the drift-nets, so numerous marked items must be released (see Appendix A).

Collections of 15 marks and fry have an 80% chance of catching natural fry if 1,000 fry are drifting among 10,000 marks (Heimbuch et al. 1990). Collections of 31 marks and fry should detect fry even if only 500 are drifting among 10,000 marks. Once even one fry is seen, then natural fry are confirmed.

RESULTS

About 40 trials with marked items were run in 1995, although only some collections have been sorted. Initial tests showed that some types of items were probably carried in the current similarly to fry. However, typical drift-net samples held few items, reducing the reliability of estimates.

About 28 trials were run in 1996, usually with larger numbers of marked items per trial. More items appeared to be caught in drift-nets, which would improve the reliability of the estimate. Nonetheless, since samples were not sorted and

counted, the numbers of fry and items are unknown.

In 10 trials from 1995 which were analyzed to date, there were no sturgeon fry among 10 to 20 marks in each sample. This means that there were probably no fry drifting, since there was 80% chance of detecting even small numbers.

At the same time, there may have been some fry drifting even though none were caught (Clopper and Pearson 1934). In samples of 10 to 20 items with no fry, there were probably fewer than 17 to 32 % fry in the drifting populations. Based on populations of 20,000 to 75,000 releases, this means that up to 6,000 to 13,000 natural fry could have drifted downstream during fry-marking trials (Appendix B).

The reliability and precision of these estimates should not be exaggerated (see Discussion).

DISCUSSION

SPAWNING

The most direct evidence of spawning at Saskatchewan River or Torch River sites is freely-running female at Bigstone Rapids, capture of several running males in the EBCampbell tailrace, Bigstone Rapids, and the mouth of the Torch River, and mature sturgeon in spillway pools. Temperatures during these observations generally agreed with those in published reports (Table 3). Observations of the swollen "ripe" state of several females is highly suggestive of spawning nearby. Sturgeon do not release their eggs easily due to an internal egg-valve, and are freely running for only a day or so (Conte et al. 1988).

The Saskatchewan River and its tributaries are generally low-gradient, so sites with rapids tend to be localized. Some observations on their present and potential suitability for spawning follow.

Torch River contains many rapids with good potential. We observed suitable habitat at least 15 km upstream, as far as Missipuskiow Creek. Fry were found 7 km upstream of the outlet, mature sturgeon were regularly caught at the mouth, and one radio-tagged adult moved up into the Torch River.

Table 3. Reported temperatures and periods of spawning of lake sturgeon.

Observation	Reference
Spawning:	
Begins at 11.7°C	Folz and Meyers (1985)
Begins at 11 - 13°C	Gendron (1988, cited in LaHaye et al. 1992)
Range 11.6 - 21°C	LaHaye et al. (1992)
Range 8.3 - 21.1°C	Kempinger (1988)
Optimal at 14 - 16°C	Harkness and Dymond (1961)
Peaks at 11.6 - 14.7°C	LaHaye et al. (1992)
Peaks 13 - 15°C	Kempinger (1988)
Peaks at 12 - 15°C	Gendron (1988)
Occurs for 4 - 10 days	Folz and Meyers (1985)
Peak spawning is 2 - 3 days	Folz and Meyers (1985)
Various species 10 - 18°C	Wang et al. 1985

Water flows have been regulated at Candle Lake for decades, but impacts on spawning are unknown. The lower few km of the Torch River (including the lowermost set of rapids) appears to back-flood when the Saskatchewan River is high.

Tobin and Squaw Rapids were formerly major rapids (Voligny 1917) and the dry river-bed still shows good substrate, ranging from cobbles to large boulders. There is only infrequent waterflow and considerable growth of grasses, bushes, and small trees on the river-bed.

EBCampbell tailrace and the "swifts" downstream comprise about 5 km of suitable cobble or stony bottom. The river-bed is physically stable, but water flows do not follow natural patterns seasonally or daily at present.

Potential spawning in the EBCampbell spillway (historically) and tailrace (presently) was indicated by upstream migration of one visually tagged sturgeon and two radio-tagged adults at spawning time. Spawning cannot be confirmed because no spawning, ripe and running adults, and no fry were observed.

Bigstone Rapids offer excellent spawning conditions. They are moderately large, and have a good substrate of large, broken rocks. Actual spawning was confirmed by a running female in 1996, and regular catches of ripe-looking sturgeon. Since waterflows are fast and deep, there may be limited rearing habitat for fry and juveniles.

Mossy River appears to have moderate spawning potential. Some spawning in the river delta or around islands is possible, but potential is likely better in the upper river (above Steamboat Channel). Catches of young sturgeon by local fishers confirm that young-of-the-year sturgeon are either produced locally or drift from upstream.

Tearing River contains widespread rocks and cobble, and is the first good spawning area upstream of Cedar Lake (Bob Fudge and Doug Leroux, pers. obs.). Diversion of water flow by a barrier at Cumberland Lake was a concern in recent years. Mature-size fish (up to 62 pounds) were caught at the junction with Saskatchewan River.

Fish and Wildlife Branch proposed a habitat-compensation project under the federal 'no net loss of fish habitat' guideline. It has not been finalized and will require further work at specific sites to assess spawning and rearing conditions. Preliminary feasibility reviews and field assessments were not undertaken with SaskPower funding, but they relate to the objectives above.

Some sturgeon populations are considerably easier to study:
1) Sturgeon in the Wolf River congregate on riprap along shorelines. Pre-spawning behaviour, sex ratios, and fish sizes can be observed, and specimens can be dip-netted for tagging or egg collection (R. Bruch and K. Kamke, Wisconsin Dept. Natural Resources, pers. comm.).

2) Spawners in the Landing River, a tributary of the Nelson River, spawn in small rapids in clear water. Spawning behaviour can be observed directly, and suitable specimens captured for egg collection (D. Leroux, Manitoba Dept. Natural Resources, pers. comm.).

3) Sturgeon in the Sturgeon River (Michigan) were easily observed during a four-year study of hydro-electric operations (Auer 1996). Length of time on site, spawning behaviour, and other details were observable.

FRY DRIFT

Lack of fry captures at all but one site (Torch River in June 1995), does not mean that fry are not drifting. It does suggest that their abundance is very low at all of our sites. Evidence for this comes from fry catches in other drift-net studies and the strong likelihood of detecting fry among marks.

Other studies show that sturgeon eggs can be either very abundant, or very low. In a healthy population, Kempinger (1988) reported 1,035 to 8,805 lake sturgeon eggs / m of substrate, and Novikova (1994) noted the normal density for beluga sturgeon is 500 eggs / m . However, artificial spawning sites may have fewer than 9.4 lake sturgeon eggs / m (LaHaye et al. 1992). Depleted populations of beluga sturgeon may produce fewer than 5 eggs / m (Novikova 1994).

Catching 5 drifting eggs or fry (as a minimum indicator of presence) was feasible in a few hours, if there was moderate abundance of sturgeon. In a population of low to moderate abundance, LaHaye et al. (1992) caught about 3 fry / hour at peak drift with similar gear. With his population, Kempinger (1988) caught 1 fry/hr at peak drift, consisting of 1.3 fry/hr at night and 0.2 in daytime, again using similar drift-nets.

A variety of gear has been used for sturgeon eggs and fry in large rivers, and may be required for any similar work in the Saskatchewan River:

(1) Artificial mats have been set to catch adhesive sturgeon eggs during spawning on deep, cobble bottom in fast currents in the Columbia River (McCabe and Beckman 1990, Marchant and Shutters 1996). The advantages are being able to sample long periods while working with greater safety in fast currents.

(2) European workers have at least a dozen drift-nets of various styles, although many of these require larger vessels and winches to operate. Guidelines for standardized surveys on large-scale projects typically require five or more nets of 0.5 to 1 m diameter (Veshchev et al. 1994).

(3) Raking the bottom upstream of a dip-net has been used in various substrates of large rivers (LaHaye et al. 1992), but was not considered suitable for spawning areas over 2.5 m deep. Their study also had low to moderate densities of eggs and fry.

Table 4. Reported temperatures and periods of incubation and drifting of lake sturgeon.

Observation	Reference
Incubation:	
Normal development 10 - 17.5 C	Wang et al. 1985
Optimal survival at 15°C	Wang et al. 1985
Hatch in 11 days at 12°C (8 days at 14 C, 6 at 16, 5 days at 18)	Wang et al. 1985
Hatch in 8 - 14 days	Kempinger (1988)
Hatch in 55 - 60 degree-days over 5.8°C (7 days at 14 C)	Kempinger (1988)
Hatch 8 days after peak spw	LaHaye et al. (1992)
Hatch 8 - 14 days after peak	LaHaye et al. (1992)
Hatch (days) = 16.6 - 0.62 * Temperature (°C)	Kohlhorst (1976), all species
Drift:	
Begins 14 days after peak spw	Provost et al. (1982, cited in LaHaye et al. 1992)
Begins 18 days after peak spw	LaHaye et al. (1992)
Begins 11 - 15 days after peak	Kempinger (1988)
Begins (days after hatch) = 28.8 - 1.1 * Temperature (°C)	Kohlhorst (1976), all species
Begins with fry 8 - 13 mm long	Kempinger (1988)
Peaks with fry 17 - 19 mm long	Kempinger (1988)
Average fry < 21 mm long at 900 m from spawning site	LaHaye et al. (1992)

The indication of low reproduction in the Saskatchewan River population (about 10% of historical levels, Wallace 1991) has not been confirmed. The earlier estimate was based on the age composition of commercially caught sturgeon.

FRY MARKING

Some studies used small wood-chips to follow salmonid or walleye movements in creeks or rivers, typically to provide time-of-travel (Franzin and Harbicht 1992). Others studied the effects of a thermal plume on nearshore fry in a large lake by modelling the currents (Elliot 1985) and then following the actual paths of buoyant radio-transmitters and estimating natural fry entrainment under different wind conditions (Carey 1985, Rodgers 1987).

Very few studies have attempted to estimate abundance of fish drifting, although McLemore et al. (1989) calculated the efficiency of a trapnet in a small river by releasing marked fish 500 m upstream. Franzin and Harbicht (1992) recommended that "Drift nets should be calibrated with concurrent use with a barrier net whenever possible, but this is impracticable in all but small streams".

Marks are entirely passive, while fry show active behaviour (Franzin and Harbicht 1992). Sturgeon and walleye fry are similar in drifting more at night and holding position more during the day (Kempinger 1988, Wallace 1987). Shortnose sturgeon fry remain on bottom and search out cover until they are nine days old, when they begin to leave cover and drift (Richmond and Kynard 1995). In one study, all five factors tested (that is, light, food, waterlevels, predatory fish, and bottom-type) had significant positive or negative influence on sturgeon fry (Vitvitskaya et al. 1994).

Although this work is tricky and results are debatable, the alternative of simply assuming there were no fry (since none were caught), was unpalatable.

WATER TEMPERATURES AND CHEMISTRY

METHODS

Data on water depths, flow velocities, and temperatures at spawning sites were collected occasionally. Water temperatures were taken with pocket-type thermometers by workers when they were on-site. In addition, minimum-maximum thermometers (Brannan-brand, cushioned inside PVC pipe) were anchored below expected low water-levels and were read and reset occasionally. Initially, there were some difficulties in reading their ascending and descending scales. During 1994, it became clear that many readings from the min-max thermometers were unusable, due to the liquid columns being regularly broken up by vibrations of river currents.

In late May 1995, a recording thermometer (Ryan-brand Temp-Mentor model) was set in the Saskatchewan River near the ferry crossing below Bigstone Rapids. It functioned for a few days until someone tampered with it (without sealing the O-ring) and caused waterlogging, so repairs were needed.

In 1996 and 1997, temperature loggers were used: Onset-brand, submersible, continuous recorders, programmed to obtain hourly temperatures, and downloaded occasionally to a pocket-size reader. The StowAway model (2 x 2.5 x 13 cm poly-carbonate) used in 1996 was enclosed in PVC pipe for protection; the Tidbit model (diameter 3 cm x 1 cm thick) in 1997 was placed in open current because it appeared more rugged.

Data on water temperatures and water chemistry were obtained for the Saskatchewan River for 1974 to 1993 (Station #00MA-05KH0001 below Carrot River in Manitoba). Environment Canada has collected samples periodically, typically four times annually (J.G. Zakreski, Water Survey of Canada pers. comm.).

The control and timing of outflow from Candle Lake (upstream on the Torch River) was an issue. To predict the timing of spawning temperatures in the Torch River from easily available data, observed water temperatures were regressed on air temperatures at two nearby climate stations. Water temperatures were taken above the Torch River outlet into the Saskatchewan River, and air temperatures Nipawin and Prince Albert airports. Data for April 1 to May 30 were used to obtain the spring warming trends. Daily mean air temperatures and cumulative air degree-days above 0°C were used.

In 1994, flow velocities at the surface and down to 1 m deep were collected with a Pygmy current meter, digital counter, and rod, working frequently from a boat. In 1995, a larger Price meter with 30-pound weight and bridge-frame holder was borrowed to assess feasibility of this work (SaskWater at Nipawin pers. comm.). In 1996 and 1997, a Global-brand flow-probe with enclosed propeller and digital readout on an extendible rod was used down to 3 m depths.

In 1994, samples of about 1 cm^3 of axial muscle were collected from commercially caught sturgeon for analysis of mercury content.

RESULTS

Water temperatures were recorded with pocket thermometers at six or seven areas (1 to 13 occasions each) during 1995 to 1997. These included Cumberland Lake, EBCampbell tailrace, Saskatchewan River (upstream of Torch River), Torch River (a few km above its outlet), and Saskatchewan River (at Bigstone Rapids and the ferry crossing) (details in Appendix C).

Some areas were more variable in temperature than others. In 1995, Bigstone Rapids area showed considerable variation, both day-to-day and between the rapids and the ferry-crossing about 1 km downstream (Figure 3). The rapids were frequently cooler (by 2 or 4°C) than the ferry site. This was probably due to warmer water from the shallow Old Channel, which enters between the two sites.

Suitable spawning temperatures are considered to be 10 to 17.5 °C since this covers the reported range, and includes the reported optimum of 12 to 15 °C (Table 3).

Temperatures in the EBCampbell area were suitable for spawning earliest in 1995 and later in both 1996 and 1997 (Figure 4). Water reached 10 °C in late-May to mid-June. Suitable temperatures lasted about two weeks in 1996, and much longer in the other years. Optimal conditions were present for shorter periods, particularly in 1996.

Spawning temperatures occurred in the Torch River consistently earlier than EBCampbell, by at least one week in 1995 and about two weeks in 1996 and 1997 (Figure 5). Temperatures in large rivers often remain cooler than tributaries in spring. Water reached 10 °C in mid-to-late May in all years. There were about 2 weeks of suitable temperatures in 1995 and 1996, and longer in 1997. Optimal temperatures lasted only a week in 1996 when warming proceeded quickly.

Bigstone Rapids reached suitable temperatures late in 1996 (similar to EBCampbell) and early in 1997 (like the Torch River)(Figure 6). Water was 10 °C by late-May to mid-June, and conditions lasted two weeks or more.

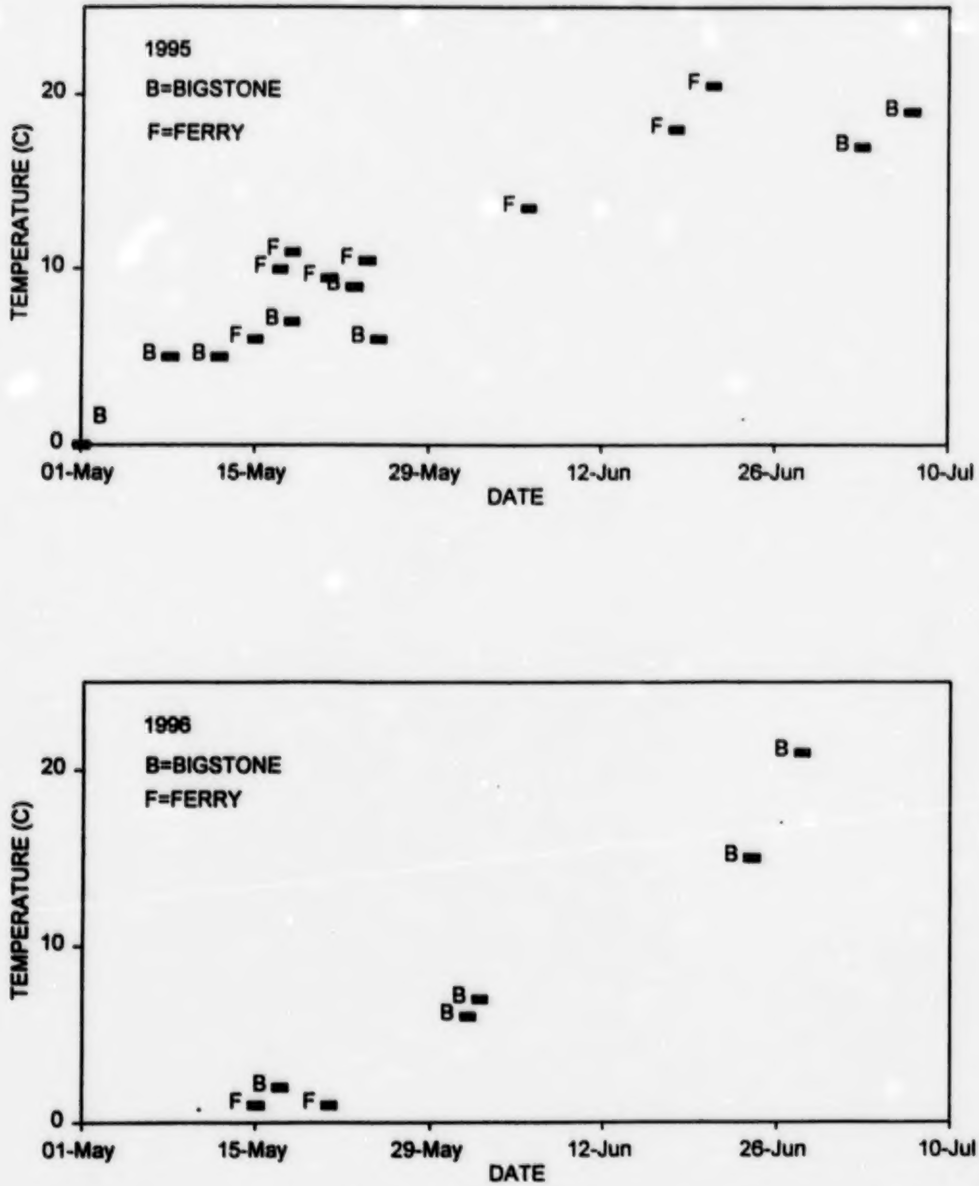


Figure 3. Variation in water temperatures near Bigstone Rapids, 1995 and 1996.

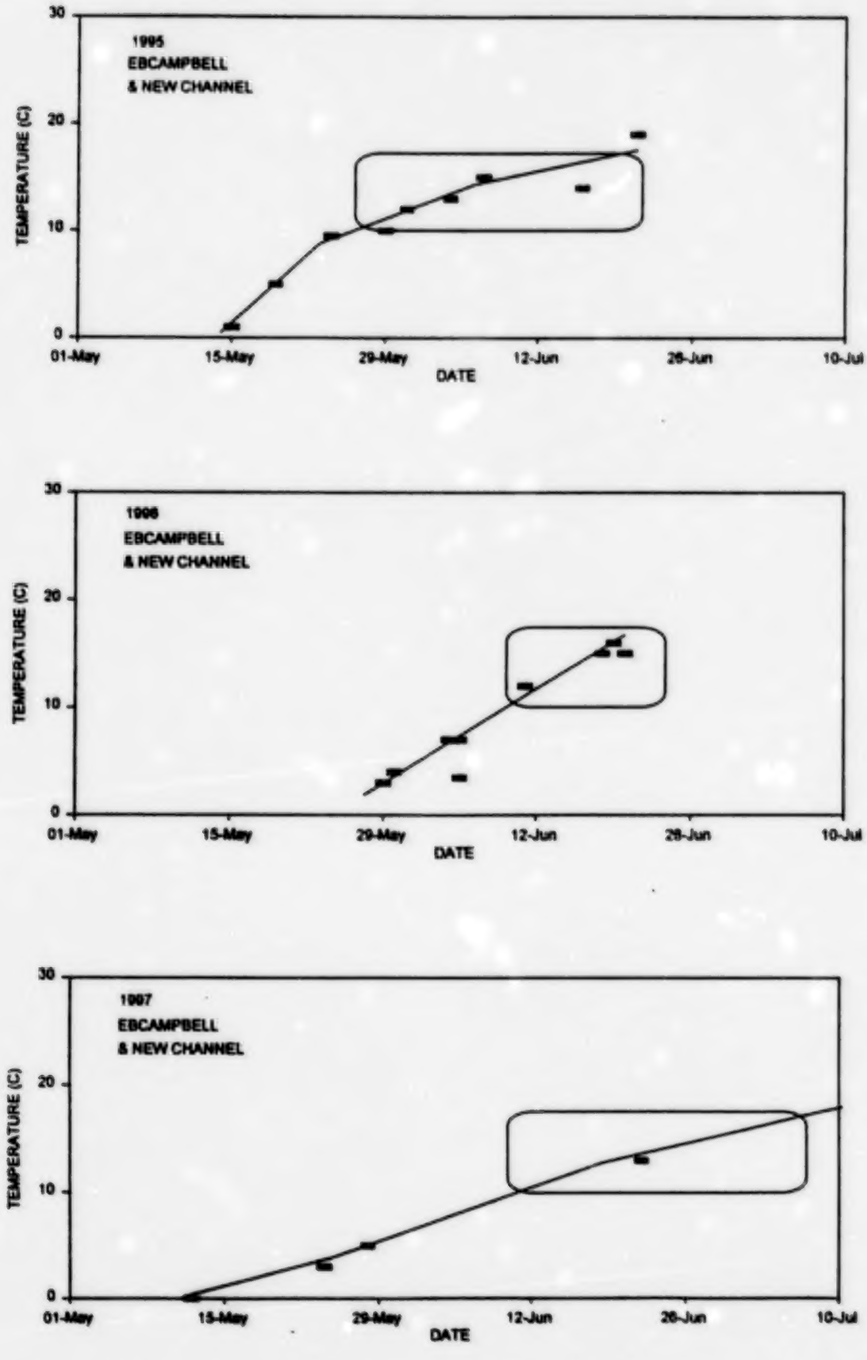


Figure 4. Dates of spawning temperatures and variations between years, EBCampbell and New Channel areas, 1995 to 1997 (see text).

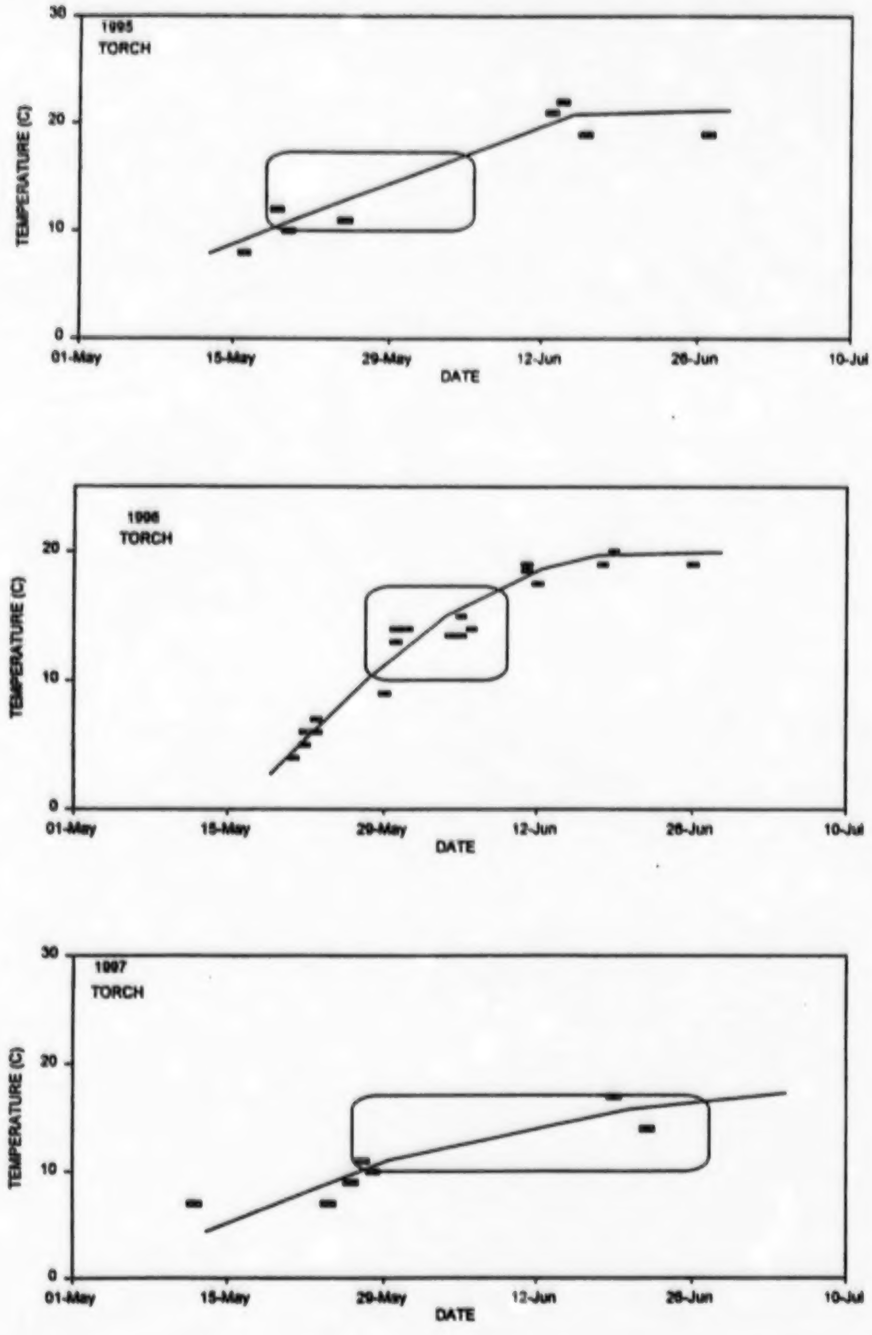
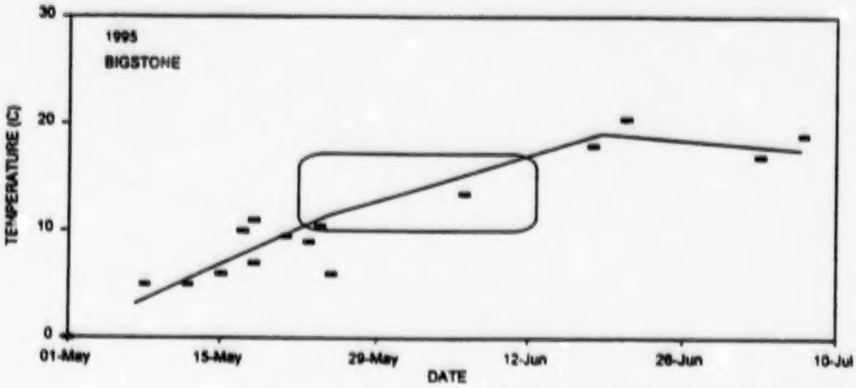
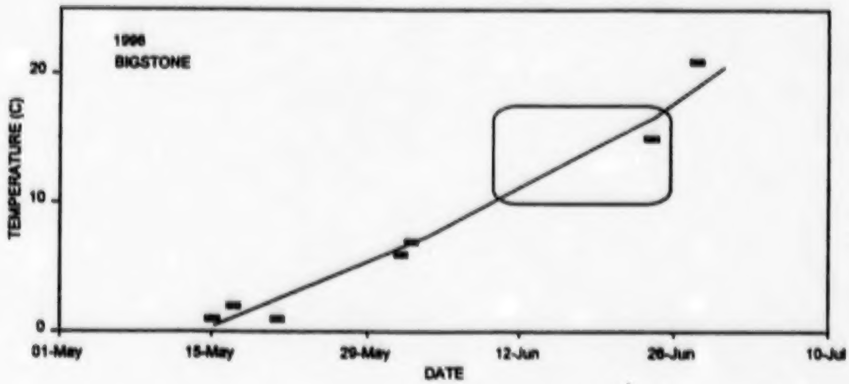


Figure 5. Dates of spawning temperatures and variations between years, Torch River, 1995 to 1997 (see text).





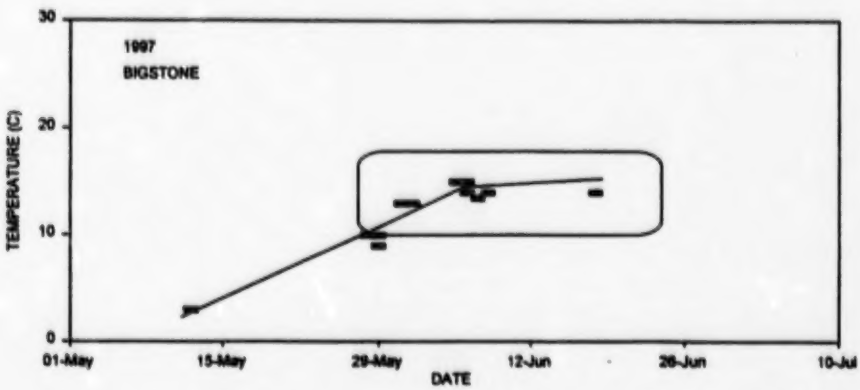


Figure 6. Dates of spawning temperatures and variations between years, Bigstone Rapids, 1995 to 1997 (see text).

Temperatures from loggers were frequently about 1 to 2°C higher than those from pocket-thermometers (Figure 7). Some of this is due to readings at nearby sites when travel to the logger site was awkward. Most was probably due to readings in surface waters by thermometer versus bottom waters by loggers, and cooling of the thermometer if reading was delayed. Some was possibly due to poor agreement of equipment: (1) Thermometers were usually checked initially with a lab-grade thermometer, but one was broken each season; (2) Pocket-thermometers were noted to disagree with each other at times; and (3) Loggers were initially checked with ice-water and warm water, but not directly against pocket-thermometers.

These discrepancies were hardly reassuring, but they did not serious affect field plans. Pocket thermometers typically suggested that activity (such as spawning) might begin earlier than actually occurred. The loggers could not be read in the field and failed to record at all in 1997; this was due to either the switch to Tidbits or to one-time errors in launching them with software.

Water in the EBCampbell area is considerably colder than downstream until early June or later. The Torch River is similar to the downstream area after mid-May, but reaches higher temperatures. Bigstone Rapids temperatures are similar or slightly cooler in May.

Water temperatures in the Saskatchewan River downstream (station 00MA05KH0001 below Carrot River) reached 10 °C about May 20 and 15 °C about June 1 on average over the 1974 to 1993 period (Figure 8). Comparisons show that warming at spawning areas in Saskatchewan during 1995 was fairly typical of long-term trends.

Warming trends in the Nipawin and Prince Albert region were not obvious due to overlap of daily air temperatures (see Appendix C). However, trends of degree-days showed a tendency for 1994 warming to arrive earlier and 1996 notably later. Water temperatures in the Torch River were predicted reasonably well from air temperatures and degree-days for the period April 1 to May 30.

The regression was:

WATER = 0.5839 + (0.3755 AIR) + (0.0174 DCC),
n=59 data, r^2 = 74.2%, mean absolute error = 2.26 °C;

where WATER is water temperature, AIR is air temperature, and DCC is degree-days of air temperatures.

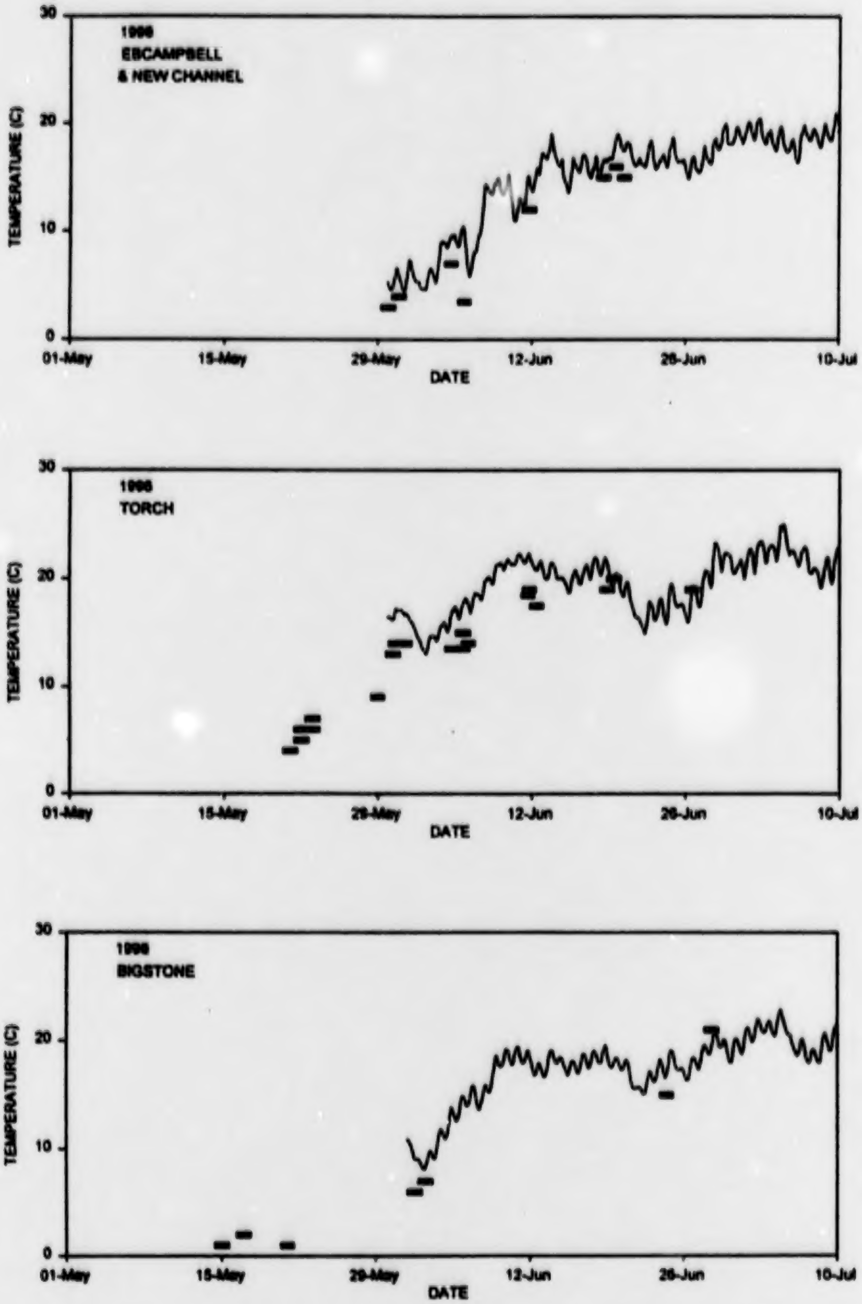


Figure 7. Trends in water temperatures in EBCampbell, Torch River, and Bigstone Rapids areas, 1996. Lines show hourly data from temperature loggers; points show individual readings from pocket thermometers.

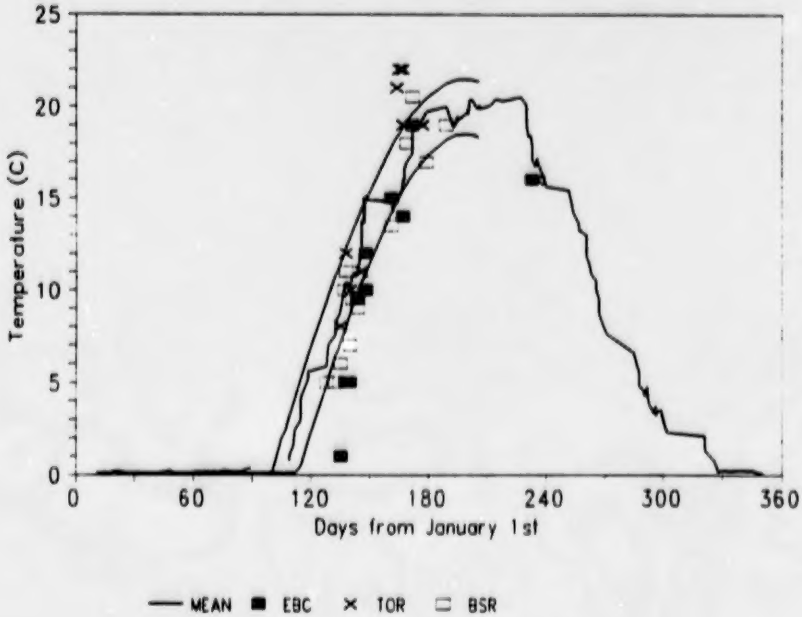


Figure 8. Water temperatures in Saskatchewan River in Manitoba, 1974 to 1993. May 1 is day 121, June 1 is day 152, and July 1 is day 182. The inner line shows a running mean of 7 days for the entire year; the smooth outer lines show warm and cool years (fitted by eye to bracket the mean). Symbols show temperatures in 1995; EBC is EBCampbell, TOR is Torch River, and BSR is Bigstone Rapids.

This regression predicts Torch River water temperatures within a band of 4.5°C from air temperatures and cumulative air degree-days in the region (see Appendix C). Data on waterflows (as discharges from the control at Candle Lake, or the Environment Canada waterflow station near Love) was not used in regressions as the data may not be available on a timely basis each year.

Time of travel for Torch River water from Candle Lake to the spawning rapids is about 6 days, assuming flow velocities are about 0.5 m/sec. Maintenance of steady releases should begin from the first date that 10°C is predicted, until 2 weeks after 15°C is predicted. This would allow travel-time prior to spawning, and incubation, hatching, and fry drift after the upper temperature of spawning.

Preliminary flow velocities were used to assess several possible spawning sites, but are not reported here. Later, more detailed velocities were obtained for two-dimensional hydraulic modelling of usable spawning areas at several sites.

Water chemistry in the lower Saskatchewan River is similar to those for other Saskatchewan River areas (e.g. North Saskatchewan in Merkowsky 1987, South Saskatchewan in Miles and Sawchyn 1988) and habitat of other lake sturgeon populations.

Averages of water-chemistry data for May to September (1974 - 1993) are:

pH (lab, arithmetic average)	8.1
Specific conductivity (uS/cm)	366.7
Total alkalinity (mg/L)	122.9
TDS (mg/L)	208.1

The moderately high conductivity is a limiting factor for radio-tags (see Wallace and Leroux 1999).

There were no obvious trends in water quality from 1974 to 1993. Water samples collected four times annually showed occasional "spikes" in some parameters (Sask Environment 1984), but no obvious trends. Data on all parameters were provided to consultants during their work in this area for Opaskwayak Cree Nation (Findlay et al. 1995).

Mercury content was determined for 37 sturgeon caught by commercial fishers in 1994 (R. Fudge, pers. comm.):

Minimum	Maximum	Average (mg/kg)
0.04	0.31	0.18

Mercury levels increased in larger sturgeon, but the relationship was not particularly precise and would not provide clear predictions.

Comparison of these mercury levels indicated that they are similar to, or lower than, those in other stable populations (Findlay et al. 1995).

Mercury levels were analysed because of their importance to commercial fishing, not because of any known effect on sturgeon populations. They were not likely a factor in the decline of this population.

These levels are also not considered high for human consumption. Restrictions on commercial harvest and sale of fish occur at 0.5 to 1.0 mk/kg.

DISCUSSION

Spawning may occur at slightly higher temperatures in rivers or in years which show more rapid warming (Folz and Meyers 1985), as observed for walleye (Rawson 1957). This implies there may be a minimum time-period for final egg or sperm maturation, or for pre-spawning behaviour.

Observations suggest that ripening of females occurs in warmer tributaries, rather than cooler mainstem rivers (D. McDonald, Manitoba Dept. of Natural Resources, pers. comm.). Presumably, they adjust the rate of final maturation of eggs, and time their spawning behaviour, with local movements into suitable temperatures. This may explain the usual abundance of ripe-looking sturgeon at the Torch River outlet.

Regulation of outflows from Candle Lake began about 1939, and became an issue for sturgeon spawning in the lower rapids of Torch River. At least one large sturgeon (over 40 kg, or 100 pounds) was sighted and killed in June 1996 below Candle Lake, after habitat assessments and the capture of fry re-confirmed spawning in lower rapids. The dates of likely spawning are variable, but can be predicted reasonably well using only regional air temperatures.

The use of data on waterflows (as discharges from the control at Candle Lake, or the Environment Canada station at Love) was not attempted as it may not be available on a timely basis.

The feasibility of using spikes in water chemistry to confirm the ageing of sturgeon was checked. This would use lasers to evaporate small sections in fin-rays and determine concentrations of individual elements (such as strontium or lead) in each annulus ("growth ring")(Veinott 1996). This might provide a specific calendar year for each annulus. However, there were technical issues to resolve and substantial costs,

and it was not pursued further (Veinott and Evans 1999).

An alternative way to confirm ageing uses the patterns of growth in fin-rays, caused by variations in water temperatures and other factors. This method creates a "master chronology" to show good and poor years of growth for reliably aged sturgeon (Cyterski and Spangler 1996). From this, the best fit of growth patterns from other fin-rays would indicate the year-class and age of other individuals. This work is presently underway using fin-rays of Saskatchewan River specimens caught from 1975 to 1994 and fin-rays from other populations, and looks promising (G. LeBreton, Univ. of Guelph, pers. comm.).

GENERAL HABITAT AND FOOD SUPPLY

In 1994, depth-sounding was done along river channels to compare general conditions within Saskatchewan and Manitoba and to other populations. The amount and location of deeper areas were of particular interest since sturgeon are reported to use them over-winter and mid-summer. Deep water also limits the range of radio signals, and therefore was a concern in our plans to track radio-tagged fish (Wallace and Leroux 1999).

Since sturgeon are bottom-feeders, we sampled different areas to assess food conditions generally. We looked for effects of bottom material, location and type of channel, water depth, and water level fluctuations on abundance of organisms.

METHODS

About 200 km of soundings were taken in June 1994, using a Sci-Tex paper-chart sounder. We recorded for ranges 0 to 10, 0 to 20, or 0 to 50 feet depending on depths in the area. In the first few days, the project workers showed that most deep areas were well known to local people. Initially, we obtained depths along the mid-line of channels to show meanders and allow accurate mapping. Later, we followed the line of deepest depth in channels. Some areas (e.g. North Angling River and Steamboat Channel) were not accessible at 'normal' waterlevels; they were done in August 1994 during episodes of high water, which added about 0.7 m to depths.

Recordings were mapped and maximum depths were noted for each section; "typical" depths were determined by eye as a general index of fish habitat. Waterlevels were recorded at several sites, but there was no attempt to relate channel depths to flows: (1) Flows varied annually, monthly, and daily, but were unknown for most areas; (2) Fluctuations varied from site to site, particularly in upper Saskatchewan River; (3) Several mainstem and tributary rivers contribute to flows and their influences vary.

We attempted to sound cross-sectional depths near spawning sites and representative areas. Results were unsatisfactory because available equipment was unsuitable: near-shore areas were frequently too shallow to operate boats; fast currents in deeper areas usually prevented a constant recording speed; recording distances from shore with forester-type walking lines or taglines did not work; and over-hanging trees interfered in some near-shore areas. In one notable instance below Bigstone Rapids, the water was 5 m (16 feet) deep on one side of the

boat while the other side was tight against shore. Several cross-sections in the New Channel area were recently found to be similar to surveys done about 1955 (N.D. Smith, University of Chicago, pers. comm.).

To assess food conditions, samples were taken from the river and lake bottom using an Ekman-type dredge. This gear penetrates the bottom for several cm, and traps both bottom materials and any clams, worms, and other aquatic invertebrates (or `bugs'). About 4 samples were taken at each river site (one in each of the 0 to 1, 1 to 2, 2 to 3, and over 3 m depths). A second set of 4 samples were taken nearby on the opposite side of the channel to ensure that both slower and faster currents were sampled. Type and amount of bottom material and specimens were noted, and samples were rinsed in netting of 11 mesh/cm on site. Samples were preserved in 5% formalin, although fragments of mollusc shells were sometimes discarded. Samples were sorted and specimens identified and weighed later.

RESULTS

River banks were observed to range from stable and treed with gentle slope to highly eroded, steep, over-hanging banks. Differences between the upper river, side-channels, and lower river have been described.

The mainstem river is mostly 2 to 5 m deep, with shallows less than 2 m deep below EBCampbell and depths 5 to 10 m along much of Centre Angling River (Figure 9).

The maximum depth found by echo-sounder in Saskatchewan was 12 m (40 feet, Centre Angling River) in early June 1994. There are substantial areas over 8 m (25 feet) deep in this river. Other deep spots included 6.5 m in the lower New Channel, 6.3 m near the Old Channel outflow, 7 m near Tearing River, and 9 m below Tearing River.

Only the lower section of Torch River was sounded and it was less than 2 m deep. The upstream areas of Mossy River were less than 2 m (above Pinebluff), while the middle area was 2 to 5 m (with shallows and some small rapids), and lower areas 2 to 5 m, with some spots 6.7 to 7 m deep.

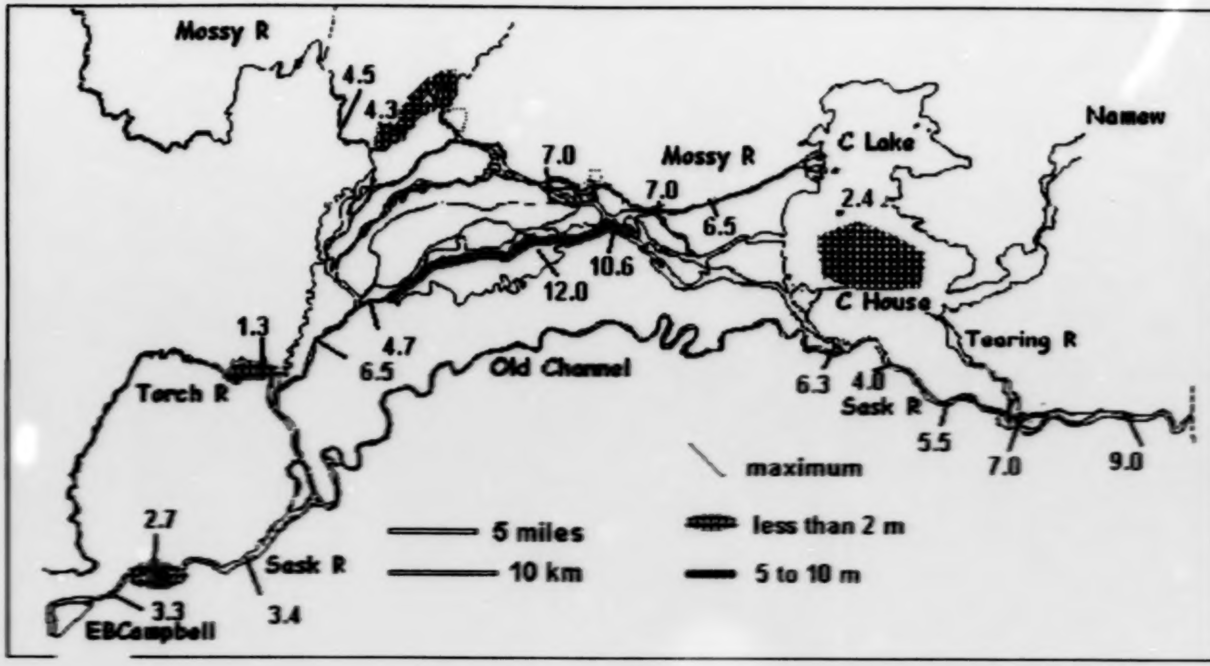


Figure 9. Map of generalized water depths in river channels, 1994 and 1995. Mainstem channel and Mossy River are 2 to 5 m deep if there is no symbol. Cumberland Lake is less than 2 m deep, but is not entirely marked. Maximum spot depths of channels are shown; minimum depths are 1 m or less.

Most other side-channels were not sounded as they are less than 1 m (3 feet) and not easily accessible to boats at typical river-flows. The exception, North Angling River in August 1994, was less than 2 m deep and mostly 1 m deep. Sharp bends in the channel were noted for being deeper, reaching 1.3 to 2.3 m.

Cumberland Lake is generally less than 2 m (6 feet) deep.

Regarding food conditions, about 127 bottom samples were taken in 1994 and analyzed. Another 32 were taken in 1995 from previously missed areas, but have not been analyzed (Figure 10).

Most of the samples had few organisms, and some had numerous specimens (Figure 11), which is common to many bottom-fauna surveys.

Results show food conditions vary considerably depending on bottom-type. Rocky areas show zero or very few organisms, primarily because the gear is not effective in these areas (Table 5). Sandy sites have low numbers of small specimens; sites with clay bottoms have about 10 times more numbers and much larger specimens. Sites with weeds have slightly more organisms than clay areas.

The effect of water depth was less noticeable. Shallow water (less than 1 m) had fewer and smaller organisms than sites 1 to 3 m deep. This is presumably due to differences in life history of the organisms, and perhaps to effects of water level fluctuations (Fisher and LaVoy 1972). Potential foods were least abundant in the areas over 3 m deep, although individual organisms were similar in size to those in shallow waters.

Food conditions were poorest in the EBCampbell and Centre Angling areas (Table 5), where rocks and sand are common. Tributaries such as the Torch and Mossy Rivers were considerably better, since samples were taken from both rocky rapids and clay-bottom areas. Statistical tests were not done because bottom-types were generally correlated with both location along the river and with depth.

Conditions were better in clay or weedy areas (e.g. side-channels and lower Saskatchewan River) and moderately deep water. The best conditions occurred in the lower main river (downstream from Bigstone Cutoff) and in other channels. These other channels are generally shallow and slow-moving, with clay bottoms and typically warmer water.

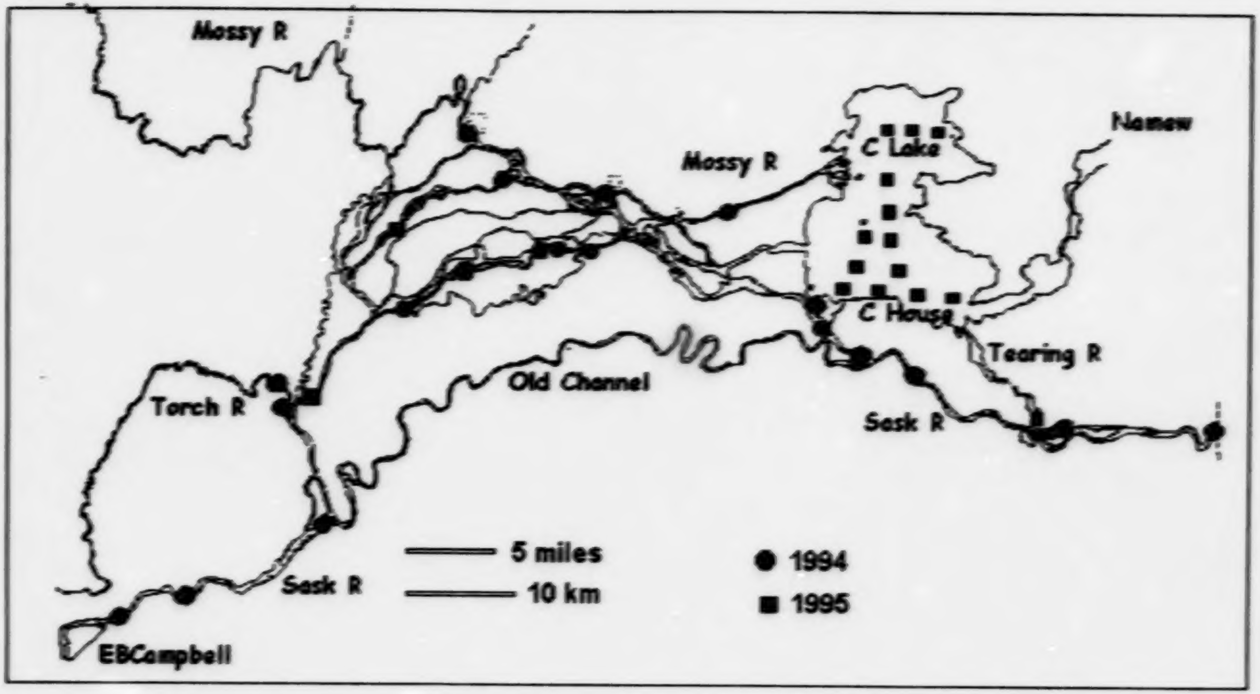


Figure 10. Locations of bottom samples collected in 1994 and 1995.

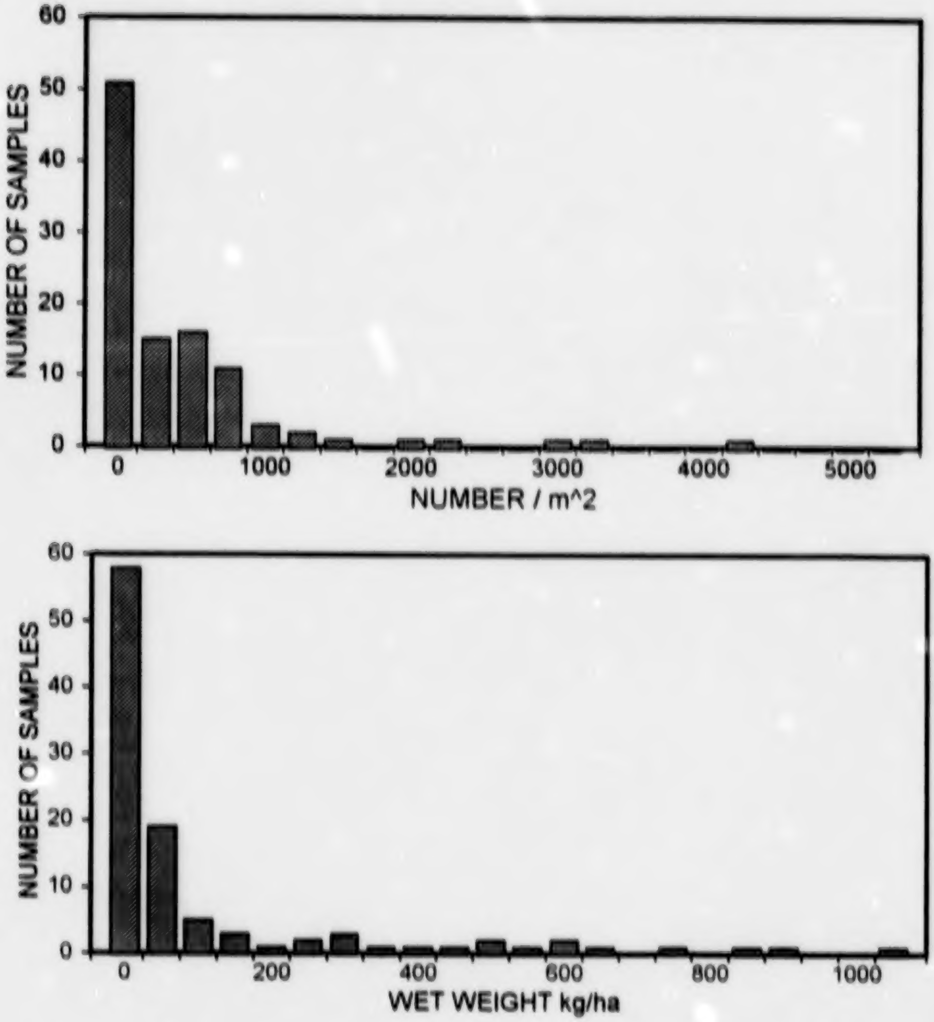


Figure 11. Number and wet weight of organisms in bottom samples, 1994 and 1995.

Table 5. Average number of bottom organisms, by bottom-type and water depth, 1994.

Description	Number (/m^2)	Weight (kg/ha)	Number samples
A) Bottom-type			
Rocks or 'Sand and small rocks'	0.0	0.0	5
Sand[a]	70.9	0.3	34
Clay or Soft clay[b]	627.3	214.5	28
Weedy or Vegetated[c]	724.0	261.8	11
B) Depth(m)			
0 - 0.9	345.8	96.3	30
1.0 - 1.9	437.0	187.2	33
2.0 - 2.9	410.1	121.9	19
3.0 - 7.9	99.8	27.4	22
C) Area[d]			
Tributaries	217.0	96.1	24
Upper mainstem	77.8	0.3	31
Lower mainstem	570.8	125.2	27
Other channels	555.5	296.2	21

[a] Excluding 'Sand & clay'.
[b] Including 'Sand & clay'; excluding 'Hard clay'.
[c] Vegetation noted, with or without sand or clay.
[d] 'Tributaries' are Torch and Mossy Rivers; 'upper mainstem' is EBCampbell and Centre Angling River; 'lower mainstem' is Bigstone Cutoff to Manitoba border; 'other channels' Steamboat, South Angling, North Angling. (see Appendix D).

DISCUSSION

General habitat conditions in the Saskatchewan River appear similar to those of other populations. There is a mixture of tributary and mainstem rapids for spawning, areas with deep holes for summer feeding or over-wintering, and channels and downstream areas for juvenile growth.

Sturgeon are typically localized, in that most studies find sturgeon in very small sites within large areas of (apparently) suitable habitat (RLL 1991, Rusak and Mosindy 1997, Seyler 1997). Problems with Saskatchewan River habitat occur at sites which are specific to spawning, and potentially nursery and juvenile activities.

Evidence for changes in depths and bottom-types in some areas are substantial. The present dominance of sand below Tobin Lake was predictable, since reservoirs allow suspended silts and bed-loads to settle and waterflows must re-acquire materials downstream. This process has deepened the Centre Angling River and Bigstone Cutoff areas, which was anticipated as early as 1915 (Voligny 1917). Meanwhile natural evolution of the delta leads to shallower side-channels (Smith et al. 1989), which may increase seasonal drying of channels. Sediment loads have declined 50% over the last 40 years at The Pas (Findlay et al. 1995).

Cumberland Lake had a maximum depth of 2.5 m under flood conditions in the 1970s (Willard et al. 1978). Large areas near shore have become shallow and overgrown with vegetation since depths were surveyed by Reed (1959). This included a few sites in both Cumberland Lake and Bigstone Cutoff which were test-netted in 1958 and are now dry (B. Fiddler and others, pers. comm.; personal observation). Waterlevels in Cumberland Lake have dropped about 1 m since 1954, partly due to reduced spring-summer flows in the Saskatchewan River (Findlay et al. 1995). In Manitoba, waterlevels in Cedar Lake rose about 2 m during its impoundment.

Some further habitat changes are expected in future, such as the possible break-through of the Bigstone Cutoff into the Old Channel (Willard et al. 1978). If this occurs near Elm Portage, flows will bypass the rapids and spawning habitat will be lost; if it occurs below Bigstone Rapids, the rapids will remain. We did not attempt to predict which scenario is more likely.

There are few known studies of sturgeon productivity which are based on general habitat indicators. Nonetheless, the effects of the loss of sediments, deepening of mainstem channel, and drying of side-channels are likely detrimental to feeding and juvenile growth.

The number of sturgeon per river-km of habitat (as reported from other studies) has been used to predict adult sturgeon abundance in the Saskatchewan River (Wallace 1991). It is more suitable for estimating historical "carrying capacity" than predicting the long-term effects of habitat changes.

Food conditions in moderate or fast currents are particularly difficult to survey, especially in deep water. There are few alternative methods for large rivers, especially deep and rocky areas. Merkowsky (1987) was limited by currents to water less than 1 or 2 m deep near each bank, using Ekman and Petersen dredges. Miles and Sawchyn (1988) used Surber samplers in shallow rocky areas, which collect any organisms dislodged from the bottom (usually by scuffling with boots). They used sweep nets in shallow vegetated areas, but rarely sampled in deeper areas using an Ekman dredge.

Other gear used in rivers include artificial substrates, such as fibrous mats, concrete blocks, rock-like objects, and floating cages. All allow colonization by drifting insects and other organisms for later counting. Some have been used on the Saskatchewan River (Cober 1968, Merkowsky 1987). Disadvantages include the difficulty of comparing the abundance or species detected, since results depend on the specific gear. Practical problems include floods or vandals carrying most of the gear away (Merkowsky 1987).

Some food sources were not detectable with our methods. Black-fly larvae can be very abundant on rocks in rapids (sometimes resembling 'carpets' according to W. Sawchyn, pers. comm.). They may be excellent prey for young sturgeon fry in spawning areas, if the fry are able to hold position and feed on the particular surfaces with attached larvae.

Young-of-the-year lake sturgeon remain on bottoms with pea-size gravel or coarse sand in shallow areas in the Wolf River (Wisconsin). They feed primarily on drifting insects associated with clean water, rather than moving into deeper downstream areas (Kempinger 1996, Choudhury et al. 1996). Similar preferences for sandy/pea-gravel bottoms in the laboratory have been shown for white sturgeon fry.

Low abundance of food, especially in the upper areas of the Saskatchewan River, may require fry and young-of-the-year to drift into other areas. Low numbers of prey are found in the mainstem river for 70 km below EBCampbell, although side-channels with high abundance of moderate-sized prey occur after 27 km. The time taken to passively drift 70 km would average 1.6 days in flows of 0.5 m/s. Fry would not arrive sooner, but substantial numbers would arrive later due to fry behaviour and delays caused by drifting itself (Kempinger 1988, Vitvitskaya

et al. 1994). Their survival would depend on the time between initiation of drift and the need to begin feeding.

Without data on the density of lake sturgeon fry in the Saskatchewan River, we can only speculate on the prey required to avoid fry starvation and/or to maximize growth. Evidence from maintenance rations and feeding behaviour might allow some approximate evaluation of required prey densities:

(1) White sturgeon (A. transmontanus) are well-studied, since they are used in aquaculture. Young white sturgeon fry and fingerlings required 4 to 5 % of their body-weight in food daily to maintain their initial weight (9 to 19 weeks old and 2 to 22 g each, Cui et al. 1996). Conversion efficiencies were highest at maximum rations of 9 to 13 % daily.

(2) Feeding trials on bester sturgeon fingerlings (H. huso x A. ruthenus) showed that longer search-times slowed consumption at food densities of 2 to 15 g/m^2, but not at 25 or more g/m^2 (Gershanovich and Taufik 1992). They ate 6.5 % and 9 % of their body-weight within two hours, respectively. These food densities are equal to 20 and 250 or more kg/ha.

(3) Field surveys of sturgeon abundance and food densities are known for only Russian and starred sturgeon (A. gueldenstaedti and A. stellatus). Due to habitat destruction in their former feeding areas by siltation, these populations shifted location. Prey densities in the former areas were not reported; young sturgeon now feed in areas with less than 200 kg/ha, although areas with over 5,000 kg/ha are available (Zolotarev et al. 1996).

Therefore, areas with 250 kg/ha of prey should allow lake sturgeon fry in the Saskatchewan River to search easily and obtain maximum rations. Prey abundance of 60 to 150 kg/ha may extend their search-time, since sturgeon use olfactory and tactile senses (that is, smell and feel) to locate food, but still allow full rations. Prey of 20 kg/ha (or less) may be limiting, since constant searching occurs and only 6.5 % rations were obtained. Searching takes energy and reduces feed-conversion efficiency, and this ration is close to the maintenance level. Sandy and upper river areas in our project have less than 1 kg/ha, which is very likely a limitation.

Food organisms for sturgeon (such as insect larvae and fingernail clams) are unusually low in Cumberland Lake. Reed (1959) found only 5.3 kg/ha, which was only 1/3 of that in Namew Lake and much lower than other lakes in southern Saskatchewan. Willard et al. (1978) noted that abundant broken clam shells indicated that the lake bottom was unstable and unsuitable for food organisms, due to constant erosion by wave action.

Lake sturgeon in the lower Saskatchewan River historically had moderate growth rates, compared to populations in Alberta, Manitoba, Wisconsin, Ontario, and Quebec (Wallace 1991 from Royer et al. 1968 and others). Recent studies of more populations (including the Saskatchewan River) showed that sturgeon maximum lengths and growth rates decreased further north and in lower river temperatures, but increased in more conductive water, which usually suggests more nutrients (Fortin et al. 1996). Another study showed that longer "growing seasons" (that is, more degree-days over 5°C air temperatures) increased the lengths and weight of age-10 and older sturgeon (Power and McKinley 1997).

Growth rates increase in northern populations, such as Saskatchewan River, but do not completely overcome the limitations of climate. The causes of this response may include better food conditions in northern populations, or more suitable water temperatures during peak seasonal prey availability (Power and McKinley 1997).

TAGGING AND MIGRATIONS

METHODS

Gill-nets and hooks similar to those used by commercial and subsistence fishermen were set for sturgeon, and other fish associated with them. Nets with 10-to 12-inch stretched mesh and Mustad-brand 9/0 hooks on 3.6-mm sideline were used. Local experience and earlier work had shown that sturgeon up to 25 kg (55 pounds) would be caught in 12-inch mesh. In some areas (such as EBCampbell and Mossy River), seines were also used to attempt to capture smaller sturgeon.

Bright orange tags were applied to the base of the dorsal fin, usually trailing backwards and upwards to minimize drag and vibrations. Tags were Floy-brand model FD-67 T-bar tags (serially numbered from N02400) in 1994 to 1996, and Hallprint-brand model TBA-1 (serial numbers from 4000) in 1997. Most fish received two T-bar tags to allow for estimates of tag-loss.

Some fish had a 1-mm hole drilled in one scute in 1994 to provide firmer anchoring and reduce skin irritation by the tag. This experiment was abandoned within weeks since use of a drill was inconvenient and increased the time needed.

Rewards were advertised and paid for the return of tags and other information, whether the recaptured sturgeon was kept or released. These were initially $3 per fish, but increased in early 1994 to $5 per tag.

In 1996 and 1997, sturgeon were also injected with a PIT tag at the base of the pectoral fin on the upper side. These are small electronic tags (sealed in glass), which sit passively until the fish is recaptured. Then a hand-held scanner is used to energize the PIT tag (from about 10 cm away), and it responds with a unique 10-character code.

To set targets for restoration of habitat and protection of this population, we wanted estimates of sturgeon abundance. We examined the feasibility of improving on our preliminary estimates of 5,000 to 16,000 sturgeon (Wallace 1991).

About 5,000 medium and large sturgeon would have lived in the river and lake habitat available before 1958, according to densities observed in other lake sturgeon populations. Between 10,000 and 16,000 medium and large sturgeon were present in 1958, according to observed mortality rates and estimated fishing rates for this population at that time.

Assuming there were about 5,000 sturgeon in 1994, we needed to

tag a minimum of 500 sturgeon and re-examine about 600 sturgeon for tags later. This would allow for estimates within ± 25% of the true abundance (Robson and Regier 1964).

RESULTS

During the project, gill-nets, hooks, and seines were used at more than 50 sites (Table 6). These captured at least ten different species, including suckers (white, buffalo, and redhorse spp.), goldeye, walleye, northern pike, yellow perch, and shiners.

In 1994, tags were applied to 10 sturgeon caught by workers and 10 small sturgeon caught by commercial fishermen who were willing to release them. Tagged fish ranged in size from 2.5 to 35 pounds (1.1 to 15.9 kg).

In 1995, tags were applied to 44 sturgeon caught by workers and commercial fishermen. Tagged fish ranged in size from 4 to 58 pounds (1.9 to 26.3 kg).

In 1996 and 1997, another 62 sturgeon were tagged, ranging in size from 5 to 54 pounds (2.2 to 24.5 kg, Figure 12 and Appendix E). This count excludes those tagged in the index fishing program (Wallace and Leroux 1999).

The length-weight relationship calculated for sturgeon tagged during 1994 - 1997 was:
Log Round weight (kg) = 3.3276 log Fork length (cm) - 5.7795, n = 133 fish, r^2 = 94%.

Early indications were that we would not achieve the required numbers of tagged sturgeon. Field-work in 1994 and 1995 actually tagged only 64 medium and large sturgeon. Furthermore, anecdotes indicate that recaptures were not all reported and the number of sturgeon re-examined is unknown. The only estimate of numbers seen is the total commercial harvest.

Table 6. Summary of fishing sites and sturgeon catches, 1994 and 1996.

Area	Dates	Number sets	Number sturgeon	Comments
EBC	Jun 1 - Jul 15	26	6	sturgeon nets & seines
Torch R	May 15 - Jul 15	55	27	mostly sturgeon nets
Mossy R	Jun 16 - Aug 15	21	0	mostly nets, some seines
CLake	Jul 15 - Aug 31	36	3	mostly hooks
Sask R	Jul 15 - Aug 31	19	2	mostly hooks & seines
Bigstone	Jun 1 - Aug 31	34	4	mostly nets & hooks
Tearing R	Aug 1 - Aug 15	2	0	all seines

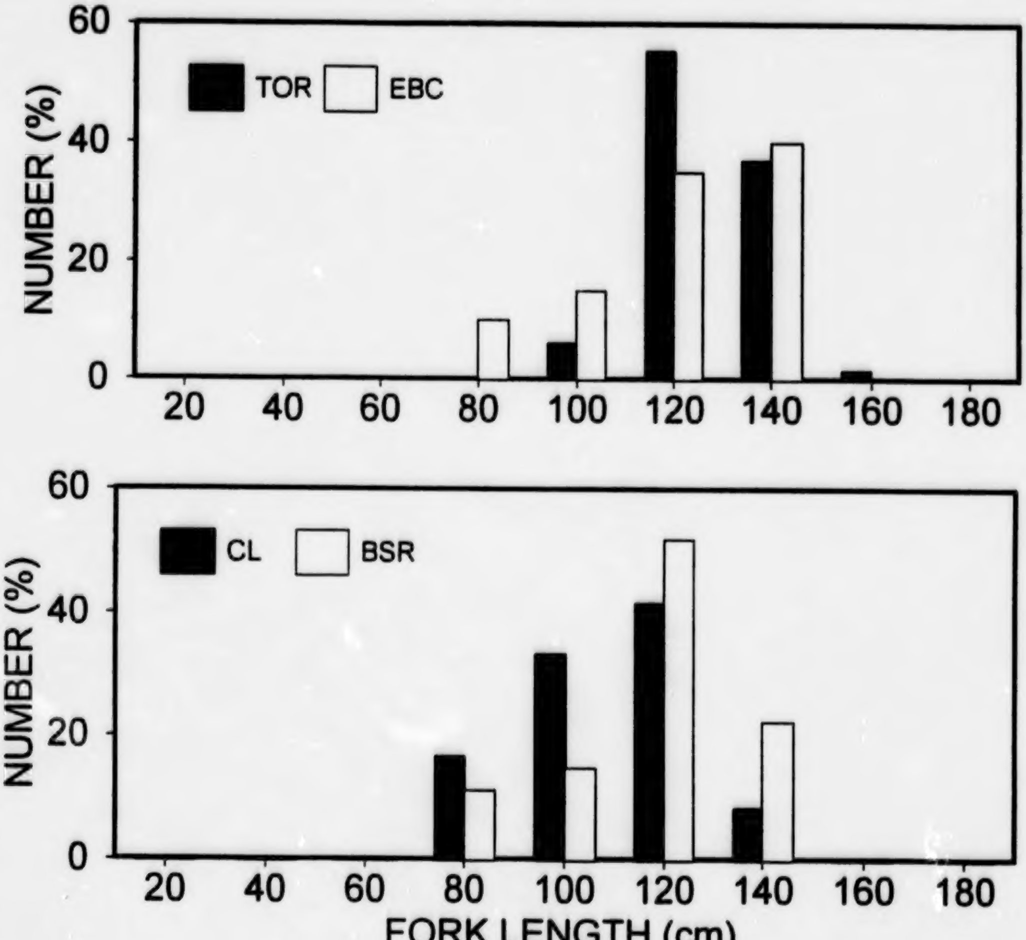


Figure 12. Sizes of sturgeon with visual tags, by year and location, 1994 to 1997. This excludes the fish caught and tagged by index fishing.

Recaptures of 2 fish were reported in 1994; another 3 were recaptured during 1995, all from 1995 tagging. In 1996 and 1997, reports were received on the recapture of 9 fish tagged from 1994 to 1997 (Table 7).

Most of the total of 14 recaptured fish were caught downstream of their tagging site. The only exceptions were the upstream migration of tag #2529 into the spillway (see Miscellaneous), and fish tagged at Torch River which were all recaptured locally (often 2 years later). Sturgeon tagged at EBCampbell were recaptured as far as Cumberland Lake, and sturgeon from Knutsons Island were recaptured in Manitoba. The greatest distance moved before recapture was at least 85 km (60 miles).

Recaptures during 1994 were made in late summer or early fall, because there were few tagged fish earlier. Recaptures in later years were concentrated in May and June, because fishing effort near spawning congregations was greater. The shortest period between tagging and recapture was overnight, for a fish at Torch River.

Recaptured fish retained 29 of 31 tags applied. One sturgeon had lost one of two tags between May 30 and June 17, only 2 weeks later. On the other hand, several sturgeon were recaptured after two years with both tags still in place. The observed rate of tag retention should allow identification of at least 80% of recaptured fish for at least a few years (Wallace and Leroux 1999).

Table 7. Observations of sturgeon recaptured with visual T-bar tags, 1994 to 1997.

1994 recaptures

#2429: Tagged 1994-June-24 at EBC Tailrace.
Caught 1994-Sept-7 in CLake (near Oldman Island).

#2438: Tagged 1994-June-28 in Centre Angling River.
Caught 1994-Sept-7 in Centre Angling River.

1995 recaptures

#2529: Tagged 1995-May-30 at EBC Tailrace.
Caught 1995-June-17 in EBC Spillway pool.

#2518: Tagged 1995-June-15 at EBC Tailrace.
Caught 1995-Aug-27 in Centre Angling River.

#2510: Tagged 1995-May-24 at Bigstone Rapids.
Caught 1995-Sept-23 at SR Birch River.

1996 recaptures

#2530: Tagged 1995-May-26 at Torch River outflow.
Caught 1996-May-31 at Torch River outflow and released.

#2587: Tagged 1996-May-22 at Torch River outflow.
Caught 1996-Jun-25 at Torch River outflow and released.

#2603: Tagged 1996-May-30 at Torch River outflow.
Caught 1996-May-31 at Torch River outflow and released.

#2583: Tagged 1996-May-22 at Torch River outflow.
Caught 1996-May-30 at Torch River outflow and released.

#nnnn: Tagged in 1984, but # missing so date and site unknown.
Caught 1996-May-31 at Torch River outflow (12 years later) and released.

1997 recaptures

#2560: Tagged 1995-Jul-05 at SR Knutsons Island.
Caught 1997-Jun-10 near Manitoba DNR Cabin at Barrier Lake and released.

continued

Table 7. cont'd

#2566: Tagged 1995-Jul?
Caught 1997-May-28 at Torch River outlet and released.

#2947: Tagged 1997-May-24 at Torch River outflow.
Caught 1997-may-26 at Torch River outflow and released.

#2466: Tagged 1995-May-19 at Torch River.
Caught 1997-May-26 at Torch River outflow and released.

#2406: Tagged 1994-Jun-10 at Torch River outlet.
Caught 2nd time 1997-May-25 at Torch River and released.

DISCUSSION

Visual tags are easy to apply and find, but rely on later recapture and reporting of information. There were several comments heard locally about fishermen not providing small sturgeon to be tagged, or not reporting all recaptured fish. There were too few recaptures during 1994 to 1997 to test the occurrence of under-reporting of tags.

The limited pursuit of commercial fishing in 1995 reduced the numbers of sturgeon being examined for tags. In 1996 and 1997, index fishing replaced commercial fishing and provided for more reliable tag retrieval and better records of sturgeon examined.

Payments were made for all tags still attached to each sturgeon at recapture. This was to improve estimates of tag loss, and to minimize any confusion about dates that might occur if some tags were not reported immediately.

Tags from recaptures were sometimes delivered by the fisherman shortly after capture, and occasionally by others much later. Rewards were delivered in all known cases, but not always promptly. Various studies have shown that prompt payment of rewards, increased reward amounts, and draws for contributors typically increase participation.

Regarding population abundance, the requirement for 500 tagged sturgeon is based on a single tagging period and single examination, and assumes that tagged sturgeon intermingle completely with non-tagged fish.

Another method of mark-recapture analysis (called Jolly-Seber) allows for greater biological realism. Factors such as concentrations of sturgeon in separate areas according to seasons and water conditions, growth of smaller fish, immigration or emigration, natural or fishing mortality, or loss of tags from fish can be examined.

Previously, the effects of numbers of tags, mortality of fish, and tag loss on estimates had been simulated for several scenarios (using BEFFJOB program of Arnason et al. 1982). These indicated that a 4-year mark-recapture survey could provide a reliable estimate of abundance (depending on the unknown factors), but success was not at all certain.

Index fishing to determine the catch-per-effort is an alternative method to follow trends in abundance. This would use the number of market-size sturgeon caught by local fishers at traditional sites. This program was implemented in 1996 (Wallace and Leroux 1999).

MISCELLANEOUS

SPILLWAY POOLS

MAY 1994

In May 1994, there were reports of sturgeon in the large pool immediately below the EBCampbell dam. A salvage operation was undertaken to capture and relocate any sturgeon (R. Fudge and H. McKenzie, pers. comm.).

Gillnets were set overnight and two sturgeon (about 7 and 14 kg, or 15 and 29 pounds) were caught. These must have over-wintered in the pool at least one winter, following the previous spill in 1993, which was the only one known for several years (Ryan Mulligan, pers. comm.) Field-workers observed a steady, small flow of water from a 6-inch pipe into this pool, and local people confirmed that open water lasted all winter.

JUNE 1995

In June 1995, water was released down the spillway channel for about one week. Following this, gillnets were set in the large pool at the dam overnight on June 16, daytime and overnight on June 17, and daytime on June 18. SaskPower co-operated by providing access and preventing any release of water at the work site (R. Fudge pers. comm.). Each set comprised four nets, each 25 yards or 22.9 m long: two 10-inch and two 12-inch mesh (25.4 and 30.5 cm mesh).

Most nets were set near the concrete 'apron' of the dam in 10 m of water, while two were set 100 to 200 m away in rocky semi-natural areas about 2 to 4 m deep. The former nets caught 3 sturgeon, and the latter 1 sturgeon. The first two sets overnight on June 16 and daytime June 17 caught all 4 sturgeon:

Fork length		Round weight		T-bar tag numbers			Comments
(cm)	(inch)	(kg)	(lb)				
136	53.5	15.5	34	2550	2551	...	none
108	42.5	10.0	22	2552	2553	...	none
135	53.2	26.3	58	2554	2556	2557	ripe female?
126	49.5	14.1	31	2529	2559	...	recapture

The lack of catches in the last two sets suggested that there were few sturgeon remaining in the pool. Lots of suckers, a few walleye and goldeye, and two smaller sturgeon (about 5 to 8 pounds) were observed by us, or reportedly seen by anglers at the dam, at the end of this netting.

All sturgeon were transported by road, then monitored for 20 minutes and released at the boat launch about 2 km downstream of the power-station. The fourth sturgeon (recaptured with tag #2529) had been tagged 1995-May-30 at the power-station and moved upstream during the period of spilling, then became isolated when the flow ceased (see Table 7 above).

AUGUST 1995

During July, there was a second release of water in the spillway. In late August 1995, all four large pools between the dam and tailrace were netted similarly by field-workers and staff (J.K. Durbin, pers. comm.). Access to the lower three pools was more difficult, and these pools were typically shallow (maximum of 2 m). A fifth pool was connected to the tailrace at least periodically and was not netted as fish had free movement.

Both large-mesh and standard-gang gill-nets were used. Each large-mesh net of 10- or 12-inch mesh (25.4 and 30.5 cm mesh) was 25 yards (or 22.9 m) long. Each standard-gang net consisted of 10-m panels of 1.5, 2, 3, 4, 5, and 5.5-inch mesh and was 60-m long.

Sets and catches are detailed for sturgeon, and summarized for other species (Table 8). Three sturgeon were caught in the large pool at the dam, all in the 5.5-inch mesh; no sturgeon were caught in other pools downstream. These sturgeon were transported and released at the boat launch downstream of the power-station:

Fork length		Round weight			
(cm)	(inch)	(kg)	(lb)	T-bar tag numbers	Comments
61	24	1.1	2.4	... ...	none
71	28	2.3	5.1	... ...	none
94	37	5.0	11.0	... ...	none

Migration of small to large sturgeon occurs when access is present. This demonstrates some interest by adults in these rapids during spawning season. Small sturgeon may also have immigrated in June, but smaller meshes were used only after the July spill. Survival over two winters suggests that oxygen conditions are suitable, although scouring of bottom materials during spills probably remove prey. Over longer periods, growth is likely affected.

Table 8. Nets set and catches in spillway pools, August 1995.

Nets	Depth	Species and number caught			
1st pool (at dam, overnight on August 21):					
2 of 10"	10 m	Sturgeon	0	Others	0
1 of 12"	10 m	Sturgeon	0	Others	0
1 of 12"	3 m	Sturgeon	0	Others	0
1 gang	2.4 to 3 m	Sturgeon	3	Walleye	18
		Sauger	6	Pike	2
		Whitefish	2	Goldeye	5
		W.Sucker	4	Redhorse	4
2nd pool (overnight August 23):					
2 of 10"	2 m	Sturgeon	0	Others	0
2 of 12"	2 m	Sturgeon	0	Others	0
1 gang	2 m	Sturgeon	0	Walleye	4
		Pike	1	Whitefish	1
		Goldeye	3	W.Sucker	6
		Redhorse	5	Perch	3
3rd pool (overnight August 22):					
2 of 10"	2 m	Sturgeon	0	Others	0
2 of 12"	2 m	Sturgeon	0	Others	0
1 gang	2 m	Sturgeon	0	Walleye	1
		Pike	3	Perch	7
4th pool (overnight August 24):					
2 of 10"	2 m	Sturgeon	0	Others	0
2 of 12"	2 m	Sturgeon	0	Others	0
1 gang	2 m	Sturgeon	0	Whitefish	2
		W.Sucker	5	Perch	8
		LN.Sucker	2		

STURGEON LANDING AND NAMEW LAKE

Reliable reports of the historical presence of sturgeon near the Sturgeon-weir River were received from several elders (e.g. Abraham Budd). There were also anecdotes of recent sightings of one sturgeon-like fish at Sturgeon Landing in 1996.

In June 1997, we viewed Namew Lake and the Sturgeon-weir River at Sturgeon Landing in a one-day visit. The objective was to assess habitat and speak to residents who may also have seen sturgeon recently.

Spawning habitat in the Sturgeon-weir River appeared to be very good: 70 to 125 m wide, moderate gradient, rocky bottom, mixed rapids and riffles, no obvious obstructions to fish movements, and no known impacts on natural flows. The river mouth is only 1500 m (1 mile) from areas in the lake which historically held sturgeon.

Recent reports of sturgeon in the river could not be confirmed, as the original observer was apparently not very familiar with sturgeon and described only a large fish like a sturgeon or pike.

Observations suggest that there are some limitation of habitat and immigration routes for sturgeon in Namew Lake. Since they prefer warm water and are predominantly bottom-dwellers, they are probably limited to areas under 15 m. These areas reach 18 to 20 C in early July and stay warm through August, while the deepest areas of Namew Lake remain below 10°C (Reed 1959). The southern sections of the lake are suitable: McDonald Bay is less than 5 m deep, and the adjacent (unnamed) section is mostly under 15 m. However, the northern section reaches 42 m (138 feet) deep and has a large open-water portion. Shallow-water areas are about 48 %, including the bay adjacent to Sturgeon-weir River.

Historical populations of sturgeon in the northern section of Namew Lake were partially isolated from the Cumberland Lake and Saskatchewan River fish. The deep water approached the shoreline, leaving only 200 to 400 m of suitable near-shore shallows. If migrations of sturgeon into Namew Lake were necessary due to local depletions or maintenance of a single population, this restriction may have been important.

CONCLUSIONS

1. The suitability of most rapids, relative to other rapids and to historical conditions cannot be assessed based on field-work alone. Ranking of spawning habitats using physical-habitat simulation models and species-preference curves appears to be necessary.

2. Several large and medium-size rapids remain available for spawning. Actual spawning in Torch River rapids and Bigstone Rapids was confirmed. Potential spawning in the EBCampbell tailrace, the former Tobin and Squaw Rapids (historically), and the Tearing River was confirmed by the presence of sturgeon in spawning condition.

3. General habitat conditions for lake sturgeon in the lower Saskatchewan River are similar to those of other populations. Deeper areas in rivers provide suitable over-wintering habitat, and many areas provide suitable food conditions.

4. Water temperatures are notably cooler below EBCampbell (for about 20 km) during spawning season than downstream in Manitoba. Food supplies of bottom-dwelling insects and other invertebrates are also lower in this area than downstream.

5. Tributary waters (such as the Torch River) reach spawning temperatures about one week earlier than Saskatchewan River sites (such as Bigstone Rapids). In turn, Bigstone Rapids is suitable at least one week earlier than EBCampbell area.

6. Proposals to restore spawning habitat at EBCampbell area to historical conditions will be complicated by cooler water at spawning time and poor food conditions nearby, as well as by the changes in flow regime. These potential limitations exist in the power-station tailrace area at present.

A second set of conclusions comes from a companion report (Wallace and Leroux 1999):

7. Radio-tags showed movements by individual sturgeon between Saskatchewan and Manitoba. They also showed considerable overlap in the stretches of river used by sturgeon tagged at different spawning sites.

8. Tracking showed the longest observed movements were 74 km upstream and 89 km downstream over 2 years. It did not show the complete migration range for the population, either for a second spawning or throughout a life-cycle.

9. Radio-tags (and visual tags) confirmed some specific habitat usage. For example:
- More sturgeon tagged at the outlet of the Torch River swam upstream to the EBCampbell tailrace than into the Torch.
- Mature-size sturgeon swam to the EBCampbell dam when waterflows occurred in the former Tobin and Squaw Rapids.
- Most mature-size fish tagged near spawning sites in Saskatchewan moved downstream after spawning season.
- More immature-size sturgeon tagged in Manitoba swam upstream and remained.
- There were long periods (up to 2 years) of little or no movement during mid-summer and over-winter.
- Radio-tagged sturgeon were found primarily in the river or near the margin of Cumberland Lake. Some may have used secondary channels during periods of undetected signals.

10. Radio-tagged sturgeon which moved downstream after release may have been drifting passively (after the stress of handling) or swimming actively (after spawning).

11. Radio-tags were lost more often than expected, due to death of sturgeon, shedding of radio-tags, non-detection of signals, or non-reporting of recaptures. Better handling and attachment techniques, and better co-operation with resource users would be helpful.

12. Determining micro-habitat preferences using radio-tags requires considerable effort. Pinpointing sturgeon is difficult in shallow water as they retreat from disturbances. Extensive surveys of utilized and available habitat were not feasible.

13. Commercial fishermen have been unable to provide enough specimens for monitoring since effort and catches have been reduced; other fisheries have not provided any specimens.

14. Index fishing allows experienced fishers to monitor traditional sites, and provides data on sturgeon sizes and abundance for comparison to both historical and future situations.

15. Index fishing showed some changes in size composition and in abundance since 1983. Both trends are consistent with further decline in population status, but are not conclusive of either decline or stability in this long-lived species.

RECOMMENDATIONS

These recommendations are based on work in both the present report and a companion report (Wallace and Leroux 1999).

Recovery of this sturgeon population depends on action on both habitat and harvests. Accordingly, actions selected from these recommendations must collectively meet the test of addressing both of these issues.

1. Management on the population should continue to be a co-operative effort of provincial agencies, communities, and resource users. This may include reviews of biological status and management options, and co-ordinated discussions with all parties. Regulatory agencies should work towards concordance in the effect of actions, even if specifics differ.

2. Protection of the habitat and protection from local over-harvest is required, especially during spawning. The objective is to have a reliable flow of water in habitat which meets the spawning needs of sturgeon. The critical period begins at water temperatures of 10°C and ends two weeks after they reach 15°C, typically from mid-May to end of June.

Specific sites of importance include:
- Tobin and Squaw Rapids were former spawning sites and are potentially suitable;
- EBCampbell tailrace is a potential spawning site;
- Torch River is a known spawning area;
- Bigstone Rapids is a large spawning and fishing site;
- Tearing River was a historical spawning site, and is again suitable for spawning;
- Summerberry River and downstream areas are potential juvenile habitat; other juvenile areas have not been found.

3. Continued harvesting of lake sturgeon from the lower Saskatchewan River (EBCampbell to Grand Rapids) will allow the present decline to continue, will probably delay the recovery of this population, and may reduce the chance of recovery over the long-term.

4. Stakeholders should seriously consider restrictions on commercial and subsistence fishing. Potential restrictions include lower (or nil) harvest quotas, the protection of spawners and spawning sites, and fewer licences or permits. Alternatively, fishers could be assured of their right-of-access to future fishing through an agreement that included the non-exercise of fishing rights for a defined period.

5. Information on subsistence fishing and cultural uses by First Nation and other aboriginal people is needed. Periodic discussions between the Steering Committee, First Nations,

consultants, and funding sources have occurred, and should be encouraged.

6. Agencies responsible for allocation and usage of water (such as SaskWater) should analyse the effects of enhancing water flows in the former Tobin and Squaw Rapids for spawning.

Specific items for analysis include:
(i) the effects of suitable, minimum, instantaneous flow for downstream sturgeon habitat versus Tobin Lake pike habitat;
(ii) the effects of higher flows during June and July (for spawning, incubation, and fry movement) on upstream and downstream users.

Assessment may require either the release of water through the spillway, or agreement among agencies that other methods provide reliable modelling of flow conditions.

7. Radio-tagging should be continued until most tags have quit, estimated as late 1999. Tracking during spring (spawning) and late-summer would be the most useful times. This can be a special program or an incidental item, as feasible.

8. Index fishing should be continued for biological, economic, and action-plan reasons. It allows for tagging and live-release of sturgeon at relatively low cost, continues the monitoring of catch rate index of abundance, and provides an alternative to continued commercial fishing.

9. Further trials of egg collection for re-stocking should be undertaken. This includes using morphological and physiological assays to identify potential spawners and determine timing, and hormone-induction of egg release. The latter requires federal regulatory approval for wild stocks, since the sacrifice of spawning females should be avoided. Recovery may be aided by re-stocking, but the potential is unproven in this population.

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Appendix A. Preliminary estimates of the number of drift-net samples needed to find sturgeon fry.

In 1994, our focus was on catching drifting eggs and fry. In their study on known spawning areas in two Quebec rivers, LaHaye et al. (1992) showed a peak of 40 - 80 eggs / 1000 m^3 in Des Prairies River and 10 - 15 eggs / 1000 m^3 in L'Assomption River. Their nets were 0.5 m diameter (0.20 m^2 mouth opening) and 'typical' flow was 0.6 m/s, so that filtering 1000 m^3 took about 2.3 hours. Catching 5 eggs (as a minimum indicator of presence) / 1000 m^3 required 0.1 to 0.8 hours of drift-netting. These two rivers probably have low to moderate egg densities.

In a depleted population of beluga sturgeon (Novikova 1994) noted a maximum egg density of 5 eggs / m^2, compared to the 'normal' 500 / m^2. Kempinger (1988) reported eggs were abundant at one site with 1,000 to 9,000 eggs / m^2.

We assumed similar numbers of eggs at our spawning sites:

- The floating drift-net is 0.15 m diameter (0.018 m^2), so 1000 m^3 at 0.6 m/s flow will take 28 hours. Therefore, 5 eggs will take 1.7 to 3.4 hours or 2 nets for 2 hours each.

- The PAIF net is 50 x 30 cm (0.15 m^2) by 180 cm total length with 11 mesh/cm of white Nitex(TM) mesh. This is similar to LaHaye's nets, so that 2 nets will take less than 1 hour. A second version of the PAIF net is 45 x 30 (0.135 m^2) by 180 cm total length with 6.5 mesh/cm of black fibreglass window-screening (B.L. Gloutney pers. comm.).

In 1995, our focus was drifting fry, rather than eggs. LaHaye et al. (1992) caught about 20 fry / hr-m^2 (of mouth opening) at peak drift. Kempinger (1988) caught 6.5 fry / hr-m^2 at peak drift, consisting of 8.9 / hr-m^2 at night and 1.0 / hr-m^2 in daytime.

Appendix B. Estimation of the number of natural sturgeon fry occurring in drift.

Typically, the relative abundance of fry is reported as numbers / volume of water through a net, based on net size and filtering efficiency (e.g. LaHaye et al. 1992). This requires the capture of fry to prove their presence, and sufficient numbers to categorize "low" and "high" catch rates.

Since no fry were observed in 1994 at any site, plans for 1995 included ensuring that low (or zero) percentages of natural fry would be detectable. The alternative to marking items was to use several times more gear for longer periods at all sites, which was not realistic. Furthermore, if natural fry were completely absent at a site, there would be no way to collect any fry regardless of effort.

Several techniques have been used to follow or estimate fry drift in fish populations (see text).

In 1995, marked items (about 10,000 to 25,000 each time) were released into the river to mix and drift with sturgeon fry, which emerge from the river-bed and drift along the bottom. This allowed determination of the proportion of natural fry in the drift, and extrapolation of total numbers of fry drifting in a period. This method depends on reasonable numbers of marked items and/or fry being recaptured in the drift-nets. Statistically, the 'sample' is the collection taken by the drift-net. The 'population' is all fry and items originating in a 100-m wide area (see below) and drifting past the drift-net while it is in place, typically overnight.

If larger collections are made, the statistical ability to find fry will increase. The size of the release and collection required to give 80% probability of finding fry was calculated from Heimbuch et al. (1990):

Number of sturgeon fry	Number needed to Collect	Number needed to Mark	Number needed to Collect	Number needed to Mark
10000	...	10000	7	50000
5000	2	10000	15	50000
1000	15	10000	80	50000
500	31	10000	160	50000
100	160	10000	804	50000

Collections of 15 marks and fry have an 80% chance of catching natural fry if 1,000 fry are drifting and 10,000 marks were released. Similarly, 31 marks and fry should reveal fry if 500 fry are drifting among 10,000 marks. Of course, once even one fry is collected, then natural fry are confirmed.

At the same time, the proportion of fry in the collection is estimated. For example, if there are no natural fry among 20 items collected, then the 'sample proportion' is 0 and natural fry potentially comprise from 0 to 16% of the drifting population. Similarly, no fry among 30 items implies that fry comprise no more than 12% of the drift (Clopper and Pearson 1934). This is not very precise, but can be improved by collecting more items. Ironically, this should be achieved with more drift-net effort, rather than releasing more marked items. The latter approach will cause the estimated maximum number of fry that could be drifting to increase.

The number of items expected in drift-nets was calculated from the sizes of nets and of the river cross-sectional area. Marked items were released near the river-bed in early 1995, and either near-bottom or on the surface later in 1995. Releases were done approximately 100 m upstream of drift-nets, far enough to ensure mixing of marks into currents but close enough to keep them from settling to the bottom or floating to the surface. Releases were spread across 100 m of open water or 100 m starting from shore in wider stretches (such as Bigstone Rapids), or across entire small rapids (e.g. Torch River). This avoided accidentally concentrating fry in 'streamlines' (Franzin and Harbicht 1992, R. Fudge pers. comm.) and provided a measured width for extrapolating drift over the entire open-channel and near-shore areas.

Items used in trials included (i) white rice and whole-grain barley dyed with food-colouring, (ii) pieces of paper 4 x 12 mm with 2-digit codes, and (iii) dead rainbow trout, lake trout, and splake yolk-sac fry provided by J. Banks (Qu'Appelle Fish Culture Station, pers. comm..) and treated with biological stains. A variety of small items (e.g. with different settling rates or buoyancy) were used to try to bracket the drift of natural fry. All items were biodegradable and were killed by microwaving (e.g. barley) or by storage in formalin (e.g. fish fry) to ensure no accidental introductions.

About 500,000 marked items were released in about 30 trials in 1995 and 1996 at Torch River, Bigstone Rapids, and EBCampbell sites. Early trials showed fewer marked items or fry in drift-net collections (than the minimum numbers needed), so larger numbers were used later.

Difficulties were encountered in releasing items near the river-bed, especially in 3 to 5 m deep areas of fast water. (1) A hand-pump and hose used to pump eggs from shallow water (Newbury and Gaboury 1993) was not effective when reversed to pump marked items, due to clogging and hydraulic pressure; (2) Pouring marks into a 4-inch diameter hose (weighted at the bottom) was feasible, although some marks spilled and work with food-colouring was messy; (3) Broadcasting items by hand was considered to be realistic only in shallow rapids.

Releasing paper marks at the surface was much simpler, and probably as suitable a method.

Very few grains of rice were collected: they may have been too friable to withstand the travel, and were relatively dense and sank quickly. Barley looked more nearly neutral in buoyancy, but the hull resisted water-soluble dyes; trials were purposely not repeated to ensure that 'bleached' barley did not re-emerge from temporary lodging during the second trial. Less than 10,000 dead fry were available, which limited trials with them. More fry from hatcheries may become available but numbers will likely remain low.

There are obvious reasons for these marked items to differ from sturgeon fry over long distances and several days. We minimized these differences by defining the population quite narrowly as marked items and fry drifting for only 100 m from the point of release, over 1-hour to 12-hour periods, in flows of 0.6 m/s or greater.

Appendix C. Water temperatures for Cumberland Lake, EBCampbell, Torch River, and Bigstone Rapids areas, 1995 to 1997.

Date	Time	Area[a]	Site	Temp (°C)
1995				
01-Jun-95	1000	CL	Gillnet site B	18.0
01-Jun-95	...	CL	Oldman Island	15.0
13-Jun-95	1120	CL	Gillnet site	18.0
19-Jun-95	1330	CL	Gillnet site C	20.0
05-Jul-95	1350	CL	Gillnet site F	19.0
15-May-95	0840	EBC	WSC station	1.0
24-May-95	1445	EBC	WSC station	9.5
29-May-95	1650	EBC	Below tailrace	10.0
31-May-95	...	EBC	Below tailrace	12.0
04-Jun-95	2105	EBC	WSC station	13.0
07-Jun-95	...	EBC	WSC mid-river	15.0
21-Jun-95	1730	EBC	WSC station	19.0
22-Aug-95	1100	EBC	WSC station	16.0
17-May-95	...	NC	Above Torch R	
19-May-95	1000	NC	Old Channel R	5.0
19-May-95	1740	NC	Above Torch R	5.0
14-Jun-95	...	NC	Above Torch R	
16-Jun-95	1000	NC	Above Torch R	14.0
09-Jun-95	...	MOR	Windy Lake	12.0
01-May-95	1450	SRB	Bigstone Rapids	0.0
08-May-95	1000	SRB	Bigstone Rapids	5
12-May-95	...	SRB	Bigstone Rapids	5
15-May-95	1000	SRF	Ferry	6.0
17-May-95	1420	SRF	Ferry	10.0
18-May-95	...	SRF	Ferry	11.0
18-May-95	1310	SRB	Bigstone Rapids	7.0
18-May-95	1230	SRF	Near ferry	?
21-May-95	1430	SRF	Near ferry	?
21-May-95	1015	SRF	Ferry	9.5
23-May-95	1530	SRB	Bigstone Rapids	9.0
24-May-95	1350	SRF	Ferry	10.5
25-May-95	...	SRB	Bigstone Rapids	6
05-Jun-95	1415	SRF	Near ferry	?
06-Jun-95	1445	SRF	Ferry	13.5

continued

Appendix C. cont'd

18-Jun-95	1700	SRF	Ferry	18.0
21-Jun-95	1630	SRF	Ferry	20.5
03-Jul-95	...	SRB	Bigstone Rapids	17.0
07-Jul-95	...	SRB	Bigstone Rapids	19.0
09-Jun-95	...	SR	Dinner Point	12.0
22-Jun-95	...	SR	Whitemans Shack	19.0
16-May-95	1930	TOR	Near outflow	8.0
19-May-95	1445	TOR	Below 1st rapids	12.0
20-May-95	1000	TOR	Near outflow	10.0
25-May-95	...	TOR	Big Rapids	11.0
13-Jun-95	2045	TOR	Big Rapids	21.0
14-Jun-95	1900	TOR	Big Rapids	22.0
15-Jun-95	...	TOR	Big Rapids	22.0
16-Jun-95	...	TOR	Big Rapids	19.0
27-Jun-95	0930	TOR	Below 1st rapids	19.0
24-Aug-95	1720	TOR	Big Rapids	16.0

1996:

01-May-96	...	SRB	...	
15-May-96	...	SRF	Ferry	1.0
17-May-96	...	SRB	Bigstone Rapids	2
21-May-96	...	SRF	Ferry	1.0
01-Jun-96	1330	SRB	Bigstone Rapids (logger)	6
02-Jun-96	...	SRB	Bigstone Rapids	7
24-Jun-96	...	SRB	Bigstone Rapids	15
28-Jun-96	...	SRB	Bigstone Rapids	21
06-Jun-96	1645	OC	Near Bell Island	12
07-Jun-96	...	OC	Near Bell Island	13
21-May-96	1600	TOR	Big Rapids	4
22-May-96	1330	TOR	Outflow	5
22-May-96	1900	TOR	Outflow	6
23-May-96	0830	TOR	Outflow	6
23-May-96	1900	TOR	Outflow	7
29-May-96	1900	TOR	Outflow	9
30-May-96	0830	TOR	Outflow	13
30-May-96	1400	TOR	Missipuskiow area	14
30-May-96	1600	TOR	Big Rapids	14
31-May-96	0900	TOR	Outflow	14
04-Jun-96	1700	TOR	Below 1st rapid (logger)	13.5

continued

Appendix C. cont'd

05-Jun-96	1245	TOR	Below 1st rapids	13.5
05-Jun-96	1530	TOR	Missipuskiow area	13.5
05-Jun-96	1530	TOR	Above Missipuskiow	15
06-Jun-96	0545	TOR	Below 1st rapids	14
11-Jun-96	...	TOR	Outflow 18.5	
11-Jun-96	1800	TOR	Below 1st rapids	19
12-Jun-96	0900	TOR	Below 1st rapids	17.5
18-Jun-96	1900	TOR	Big Rapids	19
19-Jun-96	1000	TOR	1st Rapids	20
26-Jun-96	1330	TOR	Below 1st rapids	19
29-May-96	2100	NC	Above Torch River	3
30-May-96	2100	NC	Above Torch R (logger)	4
04-Jun-96	1600	NC	Above Torch River	7
05-Jun-96	1940	EBC	WSC shoreline	3.5
05-Jun-96	2100	NC	Above Torch River	7
11-Jun-96	1800	NC	Above Torch River	12
18-Jun-96	1200	EBC	Near boat launch	15
19-Jun-96	1530	EBC	1st island downriver	16
20-Jun-96	1030	EBC	Tailrace	15
04-Jun-96	1315	SR	N.Angling outflow	8
04-Jun-96	1315	SR	Above N.Angling outflow	7
10-Jun-96	...	SR	N.Angling inflow	13
10-Jun-96	...	SR	Above N.Angling inflow	10
12-Jun-96	1030	SR	Above N.Angling inflow	12
17-Jun-96	1700	SR	Above N.Angling inflow	19
14-Jul-96	1115	SR	Above N.Angling inflow	18
06-Jun-96	1315	CL	W of Limestone Island	14
10-Jun-96	1400	TER	Outflow	20

1997:

01-May-97	...	EBC	...	
24-May-97	0930	EBC	Boat launch	3.0
12-May-97	1340	NC	Above Torch R (logger)	0.0
28-May-97	1015	NC	Above Torch River	5.0
22-Jun-97	1100	NC	Above Torch River	13.0
24-Jul-97	1515	NC	Above Torch River	20.0
12-May-97	1615	MOS	... (logger)	7.0
24-Jul-97	1900	MOS	...	22.5

continued

Appendix C. cont'd

31-May-97	1130	OC	Old Channel	13.0
12-May-97	1000	SRB	Bigstone Rapids (logger)	3.0
28-May-97	2100	SRB	Bigstone Rapids	10.0
29-May-97	2100	SRB	Bigstone Rapids	10.0
29-May-97	1015	SRB	Bigstone Rapids	9.0
31-May-97	1600	SRB	Bigstone Rapids	13.0
01-Jun-97	0930	SRF	Bridge	13.0
05-Jun-97	0400	SRB	Bigstone Rapids	15.0
05-Jun-97	2015	SRB	Bigstone Rapids	15.0
06-Jun-97	0815	SRB	Bigstone Rapids	14.0
06-Jun-97	2030	SRB	Bigstone Rapids	15.0
07-Jun-97	0915	SRB	Bigstone Rapids	13.5
08-Jun-97	0800	SRB	Bigstone Rapids	14.0
18-Jun-97	1700	SRB	Bigstone Rapids	14.0
24-Jul-97	1200	SRB	Bigstone Rapids	20.0
06-Jun-97	1200	TER	Outflow 18.5	
12-May-97	1330	TOR	Below 1st rapids (logger)	7.0
24-May-97	1900	TOR	Below 1st rapids	7.0
25-May-97	1200	TOR	Below 1st rapids	7.0
26-May-97	1630	TOR	At 1st rapids	9.0
27-May-97	1815	TOR	Below 1st rapids	11.0
28-May-97	0900	TOR	Outflow	10.0
19-Jun-97	1830	TOR	Below 1st rapids	17.0
22-Jun-97	1200	TOR	Below 1st rapids	14.0
24-Jul-97	1545	TOR	Below 1st rapids	23.0

[1] EBC=EBCampbell, NC=New Channel, OC=Old Channel, TOR=Torch River, CAN=Centre Angling River, NAN=North Angling River, SAN=South Angling River, CAD=Cadotte Channels, RAT=Ratroot Channel, STB=Steamboat Channel, BUR=Burntwood Channel, SRB=Sask. River at Bigstone Rapids, SRF=Sask. River at Ferry, CL=Cumberland Lake, TER=Tearing River, TAR=Turn-around River, MOS=Mossy River.

Appendix C. cont'd

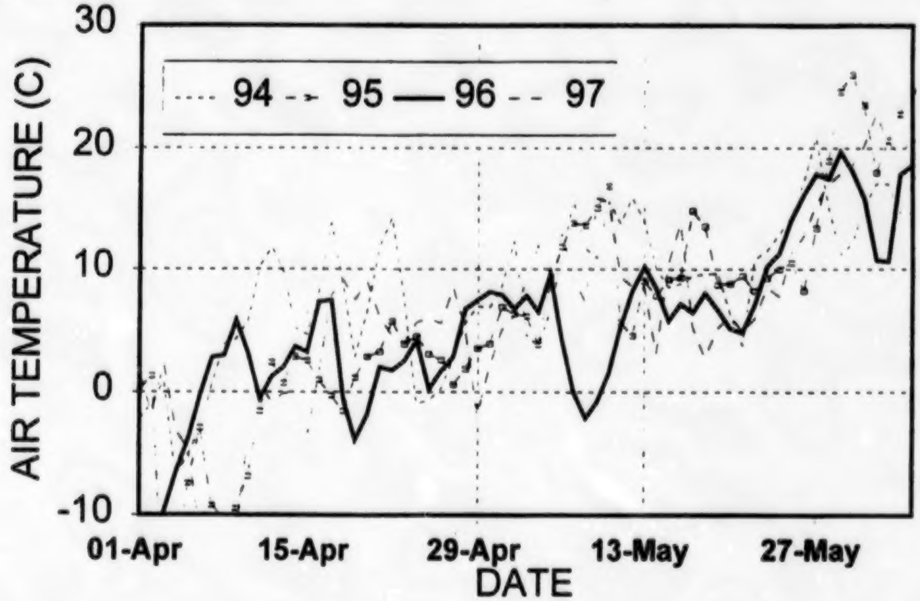

Figure C1. Average of daily mean air temperatures for two climate stations (Nipawin and Prince Albert airports) for April 1 to May 30, 1994 to 1997.

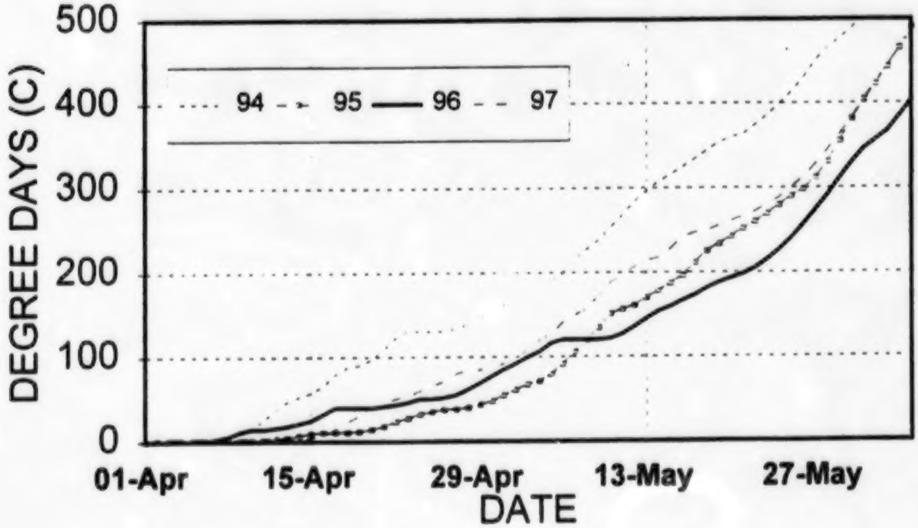

Figure C2. Cumulative degree-days for air, summed from April 1 for the same two stations.

Appendix C. cont'd

Prediction of Torch River water temperatures:

Torch River water temperatures were regressed against air temperatures, using Environment Canada climate data for Nipawin Airport (Station 4075518, WMO #711300) and Prince Albert Airport (Station 4056240, WMO #718690)[from website www.tor.ec.gc.ca/csc].

Daily means from the two weather stations showed excellent correlation, so they were averaged.

Regressions of Torch water versus average air and degree-days showed:

WATER = 0.5839 + (0.3755 AIR) + (0.0174 DCC),
n=59 data (3 in 1994, 9 in 1995, 35 in 1996, 9 in 1997),
r^2 = 74.2%, mean absolute error = 2.26 °C,

where WATER (°C) is Torch River water temperatures;
AIR (°C, as daily mean) is average for two airports;
DDC (°C, summed from April 1 for air over 0°C) is cumulative air degree-days for these two stations.

Stats package STATLETS (NWP Associate Inc. 1998) confirmed that all pairs of variable were correlated, but that simpler models with only AIR or DDC were not as suitable.

Appendix D. Food conditions determined from benthic samples, 1994 and 1995.

This field-work was frustrating because any equipment is hard to use in moderate or fast current. The most common problem was tripping of the dredge prematurely, so multiple attempts were frequently needed. No loss of bottom materials and specimens was observed when tripping occurred on bottom. A special modification to hold the lid closed during retrieval was not necessary (Murray 1975).

Adjustments to the measured 'wet weights' of bottom fauna were not used in this study. The following tables show actual weight of specimens blot-dried only since this reflects the prey abundance for fish. Traditionally, one-third of mollusc weights have been subtracted before live-weight or 'wet weight' was reported. Similarly, 'dry weight' of specimens has usually been calculated as 12% of wet weight when midge larvae (chironomids) predominate and 15% when freshwater shrimp (amphipods) predominate (Miles and Sawchyn 1988, Merkowsky 1987). Dry weights may have been more relevant to studies of bottom fauna in relation to limnological conditions.

Table D1. Number and weight of bottom organisms, 1994. The data are shown by (A) bottom-type, (B) Depth of water, and (C) Area.

A) Bottom-type	Numbers[a]	Weight(g)[a]	Number/m²	Weight kg/ha
Rocks or 'Sand & small rocks'				
Minimum	0.0	0.0	0.0	0.0
Maximum	0.0	0.0	0.0	0.0
Average	0.0	0.0	0.0	0.0
Samples	5	5	5	5
Std Dev	0.00	0.00	0.00	0.00
Sand ('Sand & clay' not included)				
Minimum	0.0	0.0	0.0	0.0
Maximum	13.0	0.0	559.6	4.3
Average	2.0	0.0	70.9	0.3
Samples	34	34	34	34
Std Dev	3.73	0.00	160.68	1.03
Clay or Soft clay ('Hard clay' not included)				
Minimum	0.0	0.0	0.0	0.0
Maximum	93.0	6.3	4003.4	2699.1
Average	14.6	0.5	627.3	214.5
Samples	28	28	28	28
Std Dev	23.66	1.24	1018.66	532.41
Weeds or Vegetation (with or without 'Sand' or 'Clay')				
Minimum	0.0	0.0	0.0	0.0
Maximum	43.0	2.0	1851.1	878.2
Average	16.8	0.6	724.0	261.8
Samples	11	11	11	11
Std Dev	13.44	0.68	578.77	291.56

continued

Table D1. continued.

B) Depth(m)	Numbers[a]	Weight(g)[a]	Number/m^2	Weight kg/ha
0 - 0.9 m:				
Minimum	0.0	0.0	0.0	0.0
Maximum	31.0	1.4	1334.5	611.3
Average	8.0	0.2	345.8	96.3
Samples	30	30	30	30
Std Dev	7.26	0.40	312.57	173.43
1.0 - 1.9 m:				
Minimum	0.0	0.0	0.0	0.0
Maximum	74.0	6.3	3185.5	2699.1
Average	10.2	0.4	437.0	187.2
Samples	33	33	33	33
Std Dev	18.15	1.17	781.49	502.57
2.0 - 2.9 m:				
Minimum	0.0	0.0	0.0	0.0
Maximum	93.0	1.9	4003.4	800.7
Average	9.5	0.3	410.1	121.9
Samples	19	19	19	19
Std Dev	21.76	0.51	936.82	217.66
3.0 - 3.9 m:				
Minimum	0.0	0.0	0.0	0.0
Maximum	0.0	0.0	0.0	0.0
Average	0.0	0.0	0.0	0.0
Samples	11	11	11	11
Std Dev	0.00	0.00	0.00	0.00
4.0 - 7.9 m:				
Minimum	0.0	0.0	0.0	0.0
Maximum	50.0	1.4	2152.4	589.8
Average	4.6	0.1	199.6	54.8
Samples	11	11	11	11
Std Dev	15.05	0.41	647.80	177.47

continued

Table D1. continued.

C) Area	Numbers[a]	Weight(g)[a]	Number/m²	Weight kg/ha
Upper main river (from EBCampbell to Centre Angling)				
Minimum	0.0	0.0	0.0	0.0
Maximum	13.0	0.0	559.6	4.3
Average	1.8	0.0	77.8	0.3
Samples	31	31	31	31
Std Dev	3.9	0.0	166.9	1.1
Tributaries (Torch and Mossy)				
Minimum	0.0	0.0	0.0	0.0
Maximum	19.0	1.9	817.9	800.7
Average	5.0	0.2	217.0	96.1
Samples	24	24	24	24
Std Dev	5.5	0.5	238.0	213.6
Lower main river (Sask.River 'Cutoff' to 'Barrier')				
Minimum	0.0	0.0	0.0	0.0
Maximum	93.0	2.0	4003.4	878.2
Average	13.3	0.3	570.8	125.2
Samples	27	27	27	27
Std Dev	22.9	0.5	984.4	226.1
Other channels				
Minimum	0.0	0.0	0.0	0.0
Maximum	66.0	6.3	2841.2	2699.1
Average	12.9	0.7	555.5	296.2
Samples	21	21	21	21
Std Dev	18.0	1.4	773.3	591.7

[a] An Ekman dredge samples an area of about 232 cm^2.

Table D2. Data on number and weight of bottom organisms, 1994 and 1995. Number and weight are for an Ekman dredge sample of about 232 cm^2.

AREA	DATEYMD	SITE	DEPTH (m)	BOTTOM-TYPE	AMOUNT (mL)	NUMBER	WET-WEIGHT (g)	SAMPLE #
SR	940707	1	0.5	CLAY,SAND,WEEDS	300	23	1.42	40
SR	940707	2	1.5	CLAY,SAND,WEEDS	300	29	2.04	42
SR	940707	3	2.5	CLAY,SAND,WEEDS	50	12	0.66	44
SR	940707	4	1.5	CLAY,SAND,WEEDS	150	12	0.86	39
SR	940707	5	0.5	CLAY,SAND,WEEDS	1000	31	0.22	45
SR	940707	6	2.5	CLAY,SAND,WEEDS	400	17	1.08	41
SR	940707	7	3.9	CLAY	20	0	0	43
CL	940708	1	0.5	CLAY,WEEDS	500	9	0.04	16
CL	940708	2	1	CLAY,SAND	250	3	0.02	10
CL	940708	3	2	HARD CLAY	0	0	0	0
CL	940708	4	0.5	CLAY	15	14	0.06	11
CL	940708	5	1	CLAY	1000	9	1.13	17
CL	940708	6	1.5	CLAY	350	66	6.27	12
EB	940712	1	0.5	SAND	150	0	0	0
EB	940712	2	1	SAND,SMALL ROCKS	300	0	0	0
EB	940712	3	2	SAND	400	0	0	0
EB	940712	4	3	ROCKS	0	0	0	0
TOR	940713	1	...	MUD,SAND	200	10	0.01	53
TOR	940713	2	2	MUD,SAND	300	3	0.02	9
TOR	940713	3	2	SAND	300	0	0	...
TOR	940713	1	...	...	...	0	0	...
TOR	940713	2	...	...	...	0	0	...
TOR	940713	3	...	...	...	0	0	...
EB	940714	1	...	...	400	0	0	...
EB	940714	2	...	...	400	0	0	...
EB	940714	3	...	...	300	0	0	...
EB	940714	1	0.5	SAND	500	0	0	...

continued

Table D2. continued

AREA	DATEYMD	SITE	DEPTH	BOTTOM-TYPE	AMOUNT	NUMBER	WET-WEIGHT	SAMPLE
EB	940714	2	1	SAND	500	5	0	1
EB	940714	3	3.5	SAND	300	0	0	...
EB	940714	1	1	ROCKS	0	0	0	0
EB	940714	2	3	ROCKS	0	0	0	0
EB	940714	3	2	ROCKS	0	0	0	0
STB	940718	1	0.5	CLAY	250	10	0.05	13
STB	940718	2	1	CLAY	150	0	0	0
STB	940718	3	1	CLAY	50	0	0	0
STB	940718	4	1.5	CLAY	50	0	0	0
STB	940718	5	0.5	VEG'N	...	0	0	0
STB	940718	6	0.75	VEG'N,SAND	300	0	0	0
STB	940718	7	1	VEG'N	...	43	0.09	37
TAR	940718	1	0.5	VEG'N,CLAY	200	9	0.28	25
TAR	940718	2	1.5	CLAY	300	0	0	...
TAR	940718	3	2.5	CLAY	250	17	1.86	14
TAR	940718	4	2	CLAY	175	0	0	...
TAR	940718	5	0.5	CLAY	175	8	0.03	20
TAR	940718	6	1.5	CLAY	250	0	0	...
TAR	940718	7	4	CLAY,SAND	300	0	0	...
TAR	940718	8	5	CLAY,SAND	500	1	0.03	22
MOS	940718	1	0.5	CLAY	100	9	0.25	26
MOS	940718	2	1	HARD CLAY	50	0	0	0
MOS	940718	3	1	HARD CLAY	50	0	0	0
MOS	940718	4	1.5	HARD CLAY	50	0	0	0
MOS	940718	5	0.5	CLAY	250	2	0.02	19
MOS	940718	6	1	CLAY	300	0	0	...
MOS	940718	7	1.5	...	200	4	0.04	36
MOS	940718	8	2	CLAY	400	2	0	15
MOS	940720	1	0.5	SOFT CLAY	1000	9	0.02	51
MOS	940720	2	1	CLAY,SAND	750	3	0.09	3
MOS	940720	3	2.5	SAND	100	0	0	0

continued

Table D2. continued

AREA	DATEYMD	SITE	DEPTH	BOTTOM-TYPE	AMOUNT	NUMBER	WET-WEIGHT	SAMPLE
MOS	940720	4	4	SAND	100	0	0	0
MOS	940720	5	0.75	SOFT CLAY	1000	12	0.24	52
MOS	940720	6	1	SOFT CLAY	400	4	0.02	4
MOS	940720	7	4	SAND	50	0	0	0
MOS	940720	8	4.5	SAND	50	0	0	0
CAN	940725	1	0.5	SAND	300	0	0	0
CAN	940725	2	1	SAND	250	0	0	0
CAN	940725	3	1.5	SAND	200	0	0	0
CAN	940725	4	2	SAND	200	0	0	0
CAN	940725	5	1	SAND	250	0	0	0
CAN	940725	6	2.5	SAND	200	0	0	0
CAN	940725	7	3	SAND	100	0	0	0
CAN	940725	8	3	SAND	100	0	0	0
CAN	940726	1	0.5	SAND	250	6	0	23
CAN	940726	2	1	SAND	350	3	0	29
CAN	940726	3	3	SAND	50	0	0	0
CAN	940726	4	5	SAND	50	0	0	0
CAN	940726	5	0.5	SAND	500	12	0.01	18
CAN	940726	6	1.5	SAND	400	13	0	35
CAN	940726	7	3	SAND	50	0	0	0
CAN	940726	8	3.5	SAND	50	0	0	0
CAN	940726	1	0.5	SAND	1000	5	0	27
CAN	940726	2	1.5	SAND	750	12	0.01	5
CAN	940726	3	2	SAND	500	0	0	0
CAN	940726	4	2.5	SAND	50	0	0	0
CAN	940726	5	0.5	SAND	500	0	0	...
CAN	940726	6	4.5	CLAY	50	0	0	0
CAN	940726	7	5.5	CLAY	50	0	0	0
CAN	940726	8	6	CLAY	20	0	0	0
SAN	940727	1	0.5	MUD CLAY	1000	2	0.23	30
SAN	940727	2	1	MUD CLAY	1000	7	0.94	31

continued

Table D2. continued

AREA	DATEYMD	SITE	DEPTH	BOTTOM-TYPE	AMOUNT	NUMBER	WET-WEIGHT	SAMPLE
SAN	940727	3	1.5	MUD CLAY	1000	10	0.76	33
SAN	940727	4	2.5	MUD CLAY	600	9	0.45	34
SAN	940727	5	3	MUD CLAY	1000	0	0	...
SAN	940727	6	4	MUD CLAY	500	50	1.37	24
SAN	940727	7	2.5	MUD CLAY	500	0	0	...
SAN	940727	8	0.5	MUD CLAY	700	0	0	...
SR	940728	1	0.5	CLAY	1000	6	0.04	7
SR	940728	2	1	CLAY,SAND	500	0	0	...
SR	940728	3	1.5	SAND	50	0	0	0
SR	940728	4	4	HARD CLAY	25	0	0	0
SR	940728	5	0.5	CLAY	1000	0	0	0
SR	940728	6	2	HARD CLAY	25	0	0	0
SR	940728	7	3	HARD CLAY	25	0	0	0
SR	940728	8	3.5	HARD CLAY	25	0	0	0
SR	940728	1	0.5	MUD,CLAY	1000	14	0.02	2
SR	940728	2	1	CLAY	500	74	0.14	28
SR	940728	3	2	CLAY	750	28	0.69	8a
SR	940728	4	2.5	CLAY	1000	93	0.62	8b
SR	940728	5	1	SOFT CLAY	2000	0	0	...
SR	940728	6	1.5	SOFT CLAY	1500	17	0.06	32
SR	940728	7	3	SAND	50	0	0	0
SR	940728	8	4	SAND	50	0	0	0
CL	940802	N/A	...	N/A	...	11	0.47	6
CL	940802	N/A	...	N/A	...	18	1.23	21
CL	940802	N/A	...	N/A	...	10	1.34	38
SR	940817	1	0.5	SAND,CLAY	1000	2	0	47
SR	940817	2	1	SAND	500	0	0	...
SR	940817	3	1.5	SAND	500	0	0	0
SR	940817	4	2.5	SAND	100	0	0	0
SR	940817	5	0.5	SAND	700	0	0	0
SR	940817	6	1.5	SAND	500	0	0	0

continued

Table D2. continued

AREA[3]	DATEYMD	SITE	DEPTH	BOTTOM-TYPE	AMOUNT	NUMBER	WET-WEIGHT	SAMPLE
SR	940817	7	2.5	SAND,HARD CLAY	100	0	0	0
TER	940817	1	0.5	CLAY	2000	7	0.57	46
TER	940817	2	1	SOFT CLAY	1500	19	1.68	48
TER	940817	3	1.5	SOFT CLAY	1000	2	0.2	49
TER	940817	4	2	SOFT CLAY	1000	0	0	...
TER	940817	5	3	SOFT CLAY	1500	0	0	...
...	...	..		...	...	2	0.16	50
---	------	---	---	---	---	---	----	---
1994 MIN=	0	0	0		0	0	0	0
1994 MAX=	940817	8	6		2000	93	6.3	53
1994 AVG=	933324	3.8	1.7		383	6.4	0.2	
1994 N =	127							
NAN	950816	A1	1.2	CLAY	100	0	0	
NAN	950816	A2	2.1	CLAY	250	0	0	
NAN	950816	A3	2.1	CLAY	100	0	0	
NAN	950816	A4	2.4	CLAY	100	0	0	
NAN	950816	B1	current too fast		...	0	0	
NAN	950816	B2	current too fast		...	0	0	
NAN	950816	B3	current too fast		...	0	0	
NAN	950816	B4	current too fast		...	0	0	
STB	950815	A1	2.4	CLAY	250	0	0	
STB	950815	A2	...	...	...	0	0	
STB	950815	A3	1.2	SAND	...	0	0	
STB	950815	A4	1.8	SAND	...	0	0	

continued

Table D2. continued

AREA	DATEYMD	SITE	DEPTH	BOTTOM-TYPE	AMOUNT	NUMBER	WET-WEIGHT	SAMPLE
STB	950815	A5	1.8	SAND	...	0	0	
STB	950815	B1	0.9	SAND	...	0	0	
STB	950815	B2	1.2	...	...	0	0	
STB	950815	B3	1.5	...	...	0	0	
STB	950815	B4	2.4	SAND	...	0	0	
CL	950805	H1	2.4	CLAY	250	0	0	
CL	950805	H2	2.4	CLAY	250	0	0	
CL	950805	H3	2.1	CLAY	750	0	0	
CL	950805	H4	2.1	CLAY	100	0	0	
CL	950805	H5	2.1	CLAY	1000	0	0	
CL	950803	J1	2.4	CLAY	500	0	0	
CL	950803	J2	2.1	CLAY	750	0	0	
CL	950803	J3	2.1	CLAY	1000			
CL	950803	J4	2.1	CLAY	1000	0	0	
CL	950803	J5	1.8	CLAY	1000	0	0	
CL	950803	T1	2.1	CLAY	250	0	0	
CL	950803	T2	1.8	CLAY	250	0	0	
CL	950803	T3	1.8	CLAY	100	0	0	
CL	950803	T4	1.8	CLAY	250	0	0	
CL	950803	T5	1.8	CLAY	400	0	0	
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1995 MIN=	950803	0	0		0	0	0	
1995 MAX=	950816	0	2.4		1000	0	0	
1995 AVG=	950810	0	1.62		270.31	0.00	0.00	
1995 N =	32							

' EB=E.B.CAMPBELL, NC=NEW CHANNEL, OC=OLD CHANNEL, TOR=TORCH RIVER, CAN=CENTRE ANGLING RIVER, NAN=NORTH ANGLING RIVER, SAN=SOUTH ANGLING RIVER, CAD=CADOTTE CHANNEL, RAT=RATROOT CHANNEL, STB=STEAMBOAT CHANNEL, BUR=BURNTWOOD CHANNEL, SR=SASK. RIVER, CL=CUMBERLAND LAKE, TER=TEARING RIVER, TAR=TURN-AROUND RIVER, MOS=MOSSY RIVER.

Appendix E. Record of sturgeon with visual T-bar tags and PIT tags applied from 1994 to 1997 (excluding index fishing), Saskatchewan.

	Caught		Released		Fork	Round	Tag numbers		
Area	Site	Date	Site (if different)	Fisherman	length (cm)	weight (kg)	1st	2ndPIT tag	Comments
CL	Oldman's Island	94Jun28		Nathan Settee	93	6.3	2440	2441	Released 7 small sturgeon.
CL	Oldman's Island	94Jun28		Ralph Cook	92	6.3	2442	2443	
CL	Oldman's Island	94Aug22		Ralph Cook	80	3.6	2452	2453	
EBC	Spillway	94Jun13	Boat launch	McKenzie/Fudge	98	6.8	2410	2412	
EBC	Spillway	94Jun13	Boat launch	McKenzie/Fudge	104	9.1	2408	2409	Good condition
EBC	Tailrace	94Jun24		McKenzie/Goulet	110	11.3	2431	2432	
EBC	Tailrace	94Jun24		McKenzie/Goulet	122	13.2	2429	2430	
EBC	Tailrace	94Jun25		McKenzie/Goulet	130	15.9	2434	2435	
MOR		94Jun16	Mossy River camp	Glen Thomas	67	1.6	2420	2419	
MOR		94Jun20	Mossy River camp	Glen Thomas	65	1.6	2423	2424	
MOR		94Jun20	Mossy River camp	Les Carriere	84	2.9	2421	2422	
MOR		94Jun22	Mossy River camp	Les Carriere	70	2.3	2427	2428	
SR	North Angling	94Jun22		James Carriere	82	4.1	2425	2426	
SR	Manitoba border	94Aug16		McKenzie/Goulet	55	1.1	2445	2444	
SR	Barrier camp	94Aug18		McKenzie/Goulet	75	2.3	2446	2447	
TER	Outflow	94Jun14		Harry Budd	79	3.2	2415	2414	
TER	Outflow	94Jun14		Harry Budd	74	2.5	2416	2417	
TOR	Outflow	94Jun10		McKenzie/Goulet	110	9.5	2406	2407	
TOR	Outflow	94Jun10		McKenzie/Goulet	121	8.6	2404	2405	
TOR	Outflow	94Jun10		McKenzie/Goulet	96	3.9	2400	2403 see 1996	

continued

Appendix E cont'd

	Caught		Released		Length	Weight	Tag numbers			
Area	Site	Date	Site (if different)	Fisherman	(cm)	(kg)	1st	2nd	PIT tag	Comments
CL	SW outlet	95Jul19		McKenzie/Goulet	108	11.0	none	none		Radio-tag #48.010 applied.
CL	SW outlet	95Jul19		McKenzie/Goulet	121	16.0	none	none		Radio-tag #48.100 applied.
CL	SW outlet	95Jul19		McKenzie/Goulet	113	13.0	none	none		Radio-tag #48.070 applied.
CL	SW outlet	95Jul20		McKenzie/Goulet	62	1.9	2563	2565		
EBC	Tailrace	95May30		McKenzie/Goulet	123	15.0	2529	2528		
EBC	Tailrace	95Jun15		McKenzie/Fudge	110	11.5	2517	2515		Mature, running male. Snout cut off.
EBC	Tailrace	95Jun15		McKenzie/Fudge	94	6.8	2525	none		
EBC	Tailrace	95Jun15		McKenzie/Fudge	120	14.7	2522	none		
EBC	Tailrace	95Jun15		McKenzie/Fudge	129	19.0	2524	2523		Possible female.
EBC	Tailrace	95Jun15		McKenzie/Fudge	119	13.8	2521	none		
EBC	Tailrace	95Jun15		McKenzie/Fudge	125	12.6	2518	2519		
EBC	Tailrace	95Jun15		McKenzie/Fudge	118	12.6	2520	none		
EBC	Spillway	95Jun17	Boat launch	Fudge/Wallace	135	26.3	2554	2556	3rd tag #2557	Possible ripe female.
EBC	Spillway	95Jun17	Boat launch	Fudge/Wallace	108	10.0	2553	2552		Tag 2553 was not applied firmly.
EBC	Spillway	95Jun17	Boat launch	Fudge/Wallace	126	14.1	2529	2559		Recaptured without tag 2528.
EBC	Spillway	95Jun17	Boat launch	Fudge/Wallace	136	15.5	2551	2550		
EBC	Tailrace	95Aug21		McKenzie/Goulet	94	5.0	2576	2577		Caught in 5.5-inch mesh.
EBC	Tailrace	95Aug21		McKenzie/Goulet	71	2.3	2574	2575		Caught in 5.5-inch mesh.
EBC	Tailrace	95Aug21		McKenzie/Goulet	61	1.1	2572	2573		Caught in 5.5-inch mesh.
SR	Bigstone Rapids	95May23	Bridge site	McKenzie/Goulet	103	8.4	2488	2489		Mature, running male.
SR	Bigstone Rapids	95May23	Bridge site	McKenzie/Goulet	96	8.2	2492	2491		Radio-tag #48.060 applied. Belly soft.
SR	Bigstone Rapids	95May23	Bridge site	McKenzie/Goulet	86	5.2	2483	2485		
SR	Bigstone Rapids	95May23	Bridge site	McKenzie/Goulet	113	11.7	2486	2487		
SR	Bigstone Rapids	95May23		McKenzie/Goulet	112	10.4	2495	2498		Mature, ripe male.
SR	Bigstone Rapids	95May23		McKenzie/Goulet	114	11.0	2493	2494		Mature, ripe male.

continued

Appendix E cont'd

Area	Caught: Site	Caught: Date	Released: Site (if different)	Fisherman	Length (cm)	Weight (kg)	Tag numbers: 1st	Tag numbers: 2ndPIT tag	Comments
SR	Bigstone Rapids	95May23		McKenzie/Goulet	124	15.0	2549	2548	
SR	Bigstone Rapids	95May23		McKenzie/Goulet	128	16.2	none	none	
SR	Bigstone Rapids	95May24		McKenzie/Goulet	113	10.0	2506	2507	Maybe 3rd tag applied?
SR	Bigstone Rapids	95May24		McKenzie/Goulet	125	14.4	2500	2501	
SR	Bigstone Rapids	95May24		McKenzie/Goulet	124	15.5	2510	2511	3rd tag 2512 applied.
SR	Bigstone Rapids	95May24		McKenzie/Goulet	123	17.5	2513	none	Radio-tag #48.080 applied. Tagging needle broke.
SR	Bigstone Rapids	95May24		McKenzie/Goulet	118	16.0	2502	2505	3rd tag # unknown
SR	Knutson's Island	95Jul05		McKenzie/Goulet	62	1.9	2560	2562	
TOR	Outflow	95May17		McKenzie/Goulet	122	13.6	2462	2463	
TOR	Outflow	95May17		McKenzie/Goulet	110	11.3	2464	2465	
TOR	Outflow	95May17		McKenzie/Goulet	117	12.7	2459	2460 see 1996	
TOR	Outflow	95May19		McKenzie/Goulet	124	13.6	2471	2469	Radio-tag #48.020 applied.
TOR	Outflow	95May19		McKenzie/Goulet	124	12.2	2479	2482	
TOR	Outflow	95May19		McKenzie/Goulet	112	8.2	2466	2467	
TOR	Outflow	95May19		McKenzie/Goulet	130	13.6	none	none	Radio-tag #48.042 applied.
TOR	Outflow	95May19		McKenzie/Goulet	114	10.0	2472	2473	
TOR	Outflow	95May19		McKenzie/Goulet	124	10.9	2475	2477	
TOR	Outflow	95May25		McKenzie/Goulet	112	13.0	2547	2546	
TOR	Outflow	95May25		McKenzie/Goulet	117	14.3	2541	2540	
TOR	Outflow	95May25		McKenzie/Goulet	99	7.6	2545	2544	
TOR	Outflow	95May25		McKenzie/Goulet	100	8.9	2543	2542	
TOR	Outflow	95May26		McKenzie/Goulet	107	14.0	2539	2538	

continued

Appendix E cont'd

	Caught		Released		Length	Weight	Tag numbers			
Area	Site	Date	Site (if different)	Fisherman	(cm)	(kg)	1st	2nd	PIT tag	Comments
TOR	Outflow	95May26		McKenzie/Goulet	123	16.9	2533	2532		
TOR	Outflow	95May26		McKenzie/Goulet	105	15.7	2531	2530		
TOR	Outflow	95May26		McKenzie/Goulet	104	10.0	2537	2536		
TOR	Outflow	95May26		McKenzie/Goulet	111	13.9	2535	2534		
TOR	Outflow	95Jun15		Goulet/Wallace	117	12.5	2526	2527		Estimated weight.
CL	Nathan's Reef	96Aug08		McKenzie/Goulet	114	12.7	2927	2928	...	
CL	Nathan's Reef	96Aug08		McKenzie/Goulet	86	3.9	2929	2930	...	
CL	Oldman's Island	96Aug26		McKenzie/Goulet	85	3.8	2932	2934	...	
SR	Bigstone Rapids	96Jun01		Goulet/Wallace	103	8.7	2619	2622	...	
SR	Bigstone Rapids	96Jun01		Goulet/Wallace	103	8.7	2619?	2622	410A621E52	
SR	Bigstone Rapids	96Jun01		Goulet/Wallace	106	9.8	2623	2624	410A683704	Male.
SR	Bigstone Rapids	96Jun01		Goulet/Wallace	111	8.5	2626	2628	410A4F1F29	Male.
SR	Bridge	96Jul24		McKenzie/Goulet	73	2.2	2925	2926	...	
TOR	Outflow	96May22		McKenzie/Goulet	110	10.0	2589	2590	...	Male (no milt).
TOR	Outflow	96May22		McKenzie/Goulet	122	16.5	2585	2586	...	Female (not ripe)
TOR	Outflow	96May22		McKenzie/Goulet	122	14.0	2580	2582	...	Male (no milt).
TOR	Outflow	96May22		McKenzie/Goulet	114	11.5	2583	2584	...	Male (no milt).
TOR	Outflow	96May22		McKenzie/Goulet	111	13.5	2587	2588	...	Male (no milt).
TOR	Outflow	96May22		McKenzie/Goulet	112	13.0	2578	2579	...	Male (no milt).
TOR	Outflow	96May30		McKenzie/Goulet	119	14.0	2591	2592	...	
TOR	Outflow	96May30		McKenzie/Goulet	121	11.5	2583	2584	...	Recapture.
TOR	Outflow	96May30		McKenzie/Goulet	106	11.0	2597	2598	...	
TOR	Outflow	96May30		McKenzie/Goulet	125	14.5	2600	2601	...	

continued

Appendix E cont'd

	Caught		Released		Length	Weight	Tag numbers			
Area	Site	Date	Site (if different)	Fisherman	(cm)	(kg)	1st	2nd	PIT tag	Comments
TOR	Outflow	96May30		McKenzie/Goulet	125	15.0	2593	2594	...	
TOR	Outflow	96May30		McKenzie/Goulet	106	9.0	2595	2596	...	
TOR	Outflow	96May31		McKenzie/Goulet	125	18.0	2614	2618	...	
TOR	Outflow	96May31		McKenzie/Goulet	106	10.0	2603	2605	...	Recapture.
TOR	Outflow	96May31		McKenzie/Goulet	107	9.5	2608	2609	...	
TOR	Outflow	96May31		McKenzie/Goulet	114	15.0	2612	2613	...	
TOR	Outflow	96May31		McKenzie/Goulet	117	15.0	2610	2611	...	Recapture # 'missing' from 1984!
TOR	Outflow	96May31		McKenzie/Goulet	119	17.5	none	none...		Radio 48.030 applies. Female.
TOR	Outflow	96May31		McKenzie/Goulet	129	17.0	2530	2602	...	Recapture. Tag 2531 caught in net.
TOR	Outflow	96May31		McKenzie/Goulet	127	21.5	none	none...		Radio 48.050 applied. Female.
TOR	Outflow	96Jun12		McKenzie/Goulet	107	8.5	2730	2731	410A53502C	Tags went together into one hole.
TOR	Outflow	96Jun25		McKenzie/Goulet	111	13.4	2587	2588	...	Recapture. Observed blunt nose.
CL	Lake	97Jun12		McKenzie/Goulet	106	8.2	2998	2999	4062645765	
CL	Lake	97Jun12		McKenzie/Goulet	106	10.4	3202	3203	4062666834	
SR	Bigstone Rapids	97May29		McKenzie/Rutherford	112	10.9	2979	2981	40627B6172	Female.
SR	Bigstone Rapids	97May30		McKenzie/Rutherford	107	9.1	2982	2983	4062736963	Running male. Penned till Jun07.
SR	Bigstone Rapids	97Jun03		McKenzie/Wallace	102	8.2	2984	2986	40625E7A52	Ripe male.
SR	Bigstone Rapids	97Jun03		McKenzie/Wallace	94	6.1	2987	2988	4063006532	Immature male.
SR	Bigstone Rapids	97Jun04		John Budd	72	2.7	2989	none...		
SR	Bigstone Rapids	97Jun04		McKenzie/Wallace	117	11.3	2996	2997	40627C3C75	Male (no milt). Penned till Jun07.
SR	Bigstone Rapids	97Jun04		McKenzie/Wallace	122	13.6	2994	2995	40627F1B08	
SR	Bigstone Rapids	97Jun04		McKenzie/Wallace	86	4.8	2990	2993	...	
TOR	Outflow	97May24		McKenzie/Goulet	104	8.3	2938	2940	40627B1D2A	

continued

Appendix E cont'd

	Caught		Released		Length	Weight	Tag numbers			
Area	Site	Date	Site (if different)	Fisherman	(cm)	(kg)	1st	2nd	PIT tag	Comments
TOR	Outflow	97May24		McKenzie/Goulet	123	13.6	2947	2949	40627C5F18	Male (no milt).
TOR	Outflow	97May24		McKenzie/Goulet	99	7.9	2944	2942	4062550D7F	Immature male?
TOR	Outflow	97May24		McKenzie/Goulet	113	12.0	2935	2936	4063013D67	Immature male?
TOR	Outflow	97May25		McKenzie/Rutherford	115	11.8	2952	2951	4062712A6A	Female (not ripe).
TOR	Outflow	97May25		McKenzie/Rutherford	106	8.6	2953	2954	4062576B4C	Male (no milt).
TOR	Outflow	97May25		McKenzie/Rutherford	112	9.5	2406	2955	410A5F1E66	Recapture. Immature male?
TOR	Outflow	97May26	Lennard's cabin	McKenzie/Goulet	119	13.8	2466	2467	4062761D65	Male.
TOR	Outflow	97May26	Lennard's cabin	McKenzie/Goulet	122	15.0	2964	2965	4062607D18	Male (milt expressed). PIT on right fin.
TOR	Outflow	97May26	Lennard's cabin	McKenzie/Goulet	138	20.4	2962	2963	4062764B4C	Male (milt expressed).
TOR	Outflow	97May26	Lennard's cabin	McKenzie/Goulet	123	14.5	2959	2958	4062735C27	Male.
TOR	Outflow	97May26	Lennard's cabin	McKenzie/Goulet	103	8.8	2960	2961	4062674251	Male.
TOR	Outflow	97May26	Lennard's cabin	McKenzie/Goulet	123	13.6	2947	2949	...	Recapture.
TOR	Outflow	97May26	Lennard's cabin	McKenzie/Goulet	139	20.9	2966	2967	40626F027F	Female (not ripe).
TOR	Outflow	97May26	Lennard's cabin	McKenzie/Goulet	136	17.7	2956	2957	406258580E	Female (not ripe).
TOR	Outflow	97May27		McKenzie/Rutherford	108	11.1	2970	2971	4062634F22	Male.
TOR	Outflow	97May27		McKenzie/Rutherford	140	22.2	2968	2969	40627E1457	Ripe female.
TOR	Outflow	97May28		McKenzie/Goulet	121	15.9	2464	2465	40625B7D47	Male.
TOR	Outflow	97May28		McKenzie/Goulet	118	13.6	2972	2973	4062622124	Male.
TOR	Outflow	97May28		McKenzie/Goulet	117	11.3	2978	2567	40627F0D58	Recapture. Tag 2566 fell off now. Male.
TOR	Outflow	97May28		McKenzie/Goulet	145	24.5	2974	2977	4062565B25	Female.